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Report for the GSM Association

and Huawei

The impact of mobile broadband in the Asia–Pacific region, and future spectrum needs

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Contents

1	**Executive summary**	**1**
1.1	Background and key findings	1
1.2	Growth in demand for mobile services	2
1.3	Socio-economic benefits of mobile broadband	4
1.4	How mobile technology is evolving	6
1.5	Spectrum implications	8
1.6	Implications	8
2	**Introduction**	**10**
2.1	Background and objectives of the study	10
2.2	Structure of this document	11
3	**Key trends**	**12**
3.1	Demand drivers in the mobile market	12
3.2	Growth forecasts	12
3.3	How mobile technology is evolving	17
3.4	How spectrum use is changing	20
4	**The impact of mobile broadband connectivity on society and the economy**	**23**
4.1	Overview of the socio-economic benefits of broadband services	23
4.2	Impact on GDP	26
4.3	Jobs created	27
4.4	Other impacts	28
5	**The need for additional spectrum**	**29**
5.1	Predicted spectrum needs	29
5.2	Meeting predicted future needs	31
5.3	Impact of further spectrum being available	35
5.4	Implications	37

Annex A Mobile broadband usage and trends – case studies
Annex B Methodology for benefits estimation
Annex C References

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1 Executive summary

This is the executive summary of a study carried out by Analysys Mason on behalf of the GSM Association (GSMA) and Huawei, to examine developments in the mobile broadband market in the Asia–Pacific region and to estimate the socio-economic benefits of these developments. The report also discusses how these benefits are dependent on sufficient spectrum being available, both to accommodate forecast subscriber and traffic needs, and to enable mobile operators to exploit the latest mobile technologies.

We would like to thank the GSMA and Huawei for the contributions and guidance that they have provided to us in producing this report.

1.1 Background and key findings

Many studies conducted in recent years have highlighted the economic impact of decisions made by national governments about the award of mobile spectrum. This impact is substantial, due to the significant reliance on mobile networks – and mobile broadband services in particular, carried over a combination of 3G and 4G networks – in today's society, both by consumers and businesses.

The results from our study, conducted between October and November 2014, show that:

- Consumers are increasingly using mobile devices to access the internet; in the Asia–Pacific region, 3 billion mobile broadband connections (3G and 4G) are expected to be active by 2020[1], consuming over 50 000 petabytes (PB) of data per year. Faster-than-expected growth is occurring in both the number of mobile data subscribers and the traffic they generate. In China, the use of 3G and 4G networks is set to result in almost 15 000 petabytes of data per year being carried on China's mobile networks by 2019 – approximately 25% of the total traffic forecast for the entire Asia–Pacific region. Data traffic in China is forecast to increase at a compound annual growth rate (CAGR) of more than 55% between now and 2019.

- Greater penetration of broadband services could lead to an increment of USD1.2 trillion in total to the economic output of the countries studied by 2020. Cumulative new jobs added to the regional economy could reach 35 million. These estimates represent the predicted effect of *broadband adoption of all types*, including mobile broadband connectivity.

- Operators are fundamentally changing the way they use existing spectrum in order to meet market needs. This includes re-farming, which requires technological innovation to enhance the efficiency and flexibility of spectrum usage, aggregating multiple carriers and deploying smaller cell overlays alongside existing macro cellular networks. Re-farming 900MHz spectrum from 2G to 3G has seen swift market uptake in the Asia–Pacific region for example

[1] Economic benefits are based on the predicted effect of increased broadband connections of all types, including mobile broadband, in the countries studied for this report, namely Australia, China, Hong Kong, India, Singapore and South Korea

with estimates from Huawei that the penetration of UMTS900 handsets is reaching 80%. One example is the re-farming of 900MHz spectrum in Hutchison's network in Hong Kong, using Huawei's single radio access network (RAN) infrastructure to provide UMTS900.

- Asia–Pacific operators lead the way in commercialising the use of multi-frequency bands to deploy LTE-A services. These developments will provide further benefits to consumers by making available the significantly better peak download speeds that LTE-A networks can deliver. However, sufficient bandwidth and spectrum must be made available to ensure operators can deploy these latest mobile technologies.

- New services, including streaming video, location-based apps and the 'Internet of Things', are all supported by today's mobile networks. As the world becomes increasingly mobile, this is leading to demand for access to services and content (including internet, social media and TV content) from any location, at any time. To meet future market needs, networks will need to accommodate different traffic loads and cater for the connection of many more types of devices.

- There is immense concern among the mobile industry that sufficient amounts of suitable radio spectrum may not be available for mobile use in the mid-term. The outcome of the World Radiocommunication Conference in 2015 (WRC-15), organised by the International Telecommunication Union (ITU), which will consider bands for future mobile use and identify specific portions of these bands for use by international mobile telecommunications (IMT), will be of great importance for the continued development of the mobile market in the Asia–Pacific region and globally.

- Concentration of incumbent services spectrum into smaller bandwidths, migrating incumbent use to other bands and a range of other options are available to national regulators and policy makers in order to release new spectrum for mobile use. Ultimately, choices should be guided by the benefits of using different bands for new mobile use, relative to the costs of alternative options to meet existing users' needs.

A selection of countries in the region are profiled as case studies in the report – China, Australia, Hong Kong, South Korea, India and Singapore – to demonstrate how the use of mobile networks is evolving in different countries, and how spectrum needs vary based on usage levels and market conditions in different markets. The case studies also highlight the importance of national spectrum assignment being coordinated within a globally harmonised spectrum framework coordinated at a regional and international level through the Radiocommunication sector of the International Telecommunication Union (ITU-R).

1.2 Growth in demand for mobile services

Mobile devices are increasingly viewed as an essential part of modern life. Recent years have seen a surge in mobile data traffic, with rates of growth in use of mobile data services significantly exceeding those of fixed networks in many markets. Forecasts suggest that mobile data will continue to grow, according to Analysys Mason forecasts. Although the rate of subscriber growth is slowing in some markets, the amount of traffic carried by networks is increasing as subscribers consume more data.

As a result, for the Asia–Pacific region, Analysys Mason forecasts that, from 2013 to 2018, the number of mobile connections will grow at a CAGR of 6% while data traffic will grow at 46%, as illustrated below.

Figure 1.1: Historical (2012–14) and forecast (2014–18) growth in mobile connections in the Asia–Pacific region [Source: Analysys Mason, 2014]

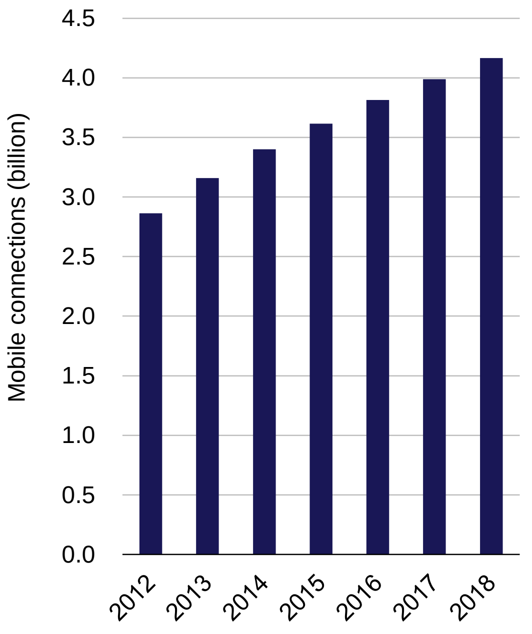
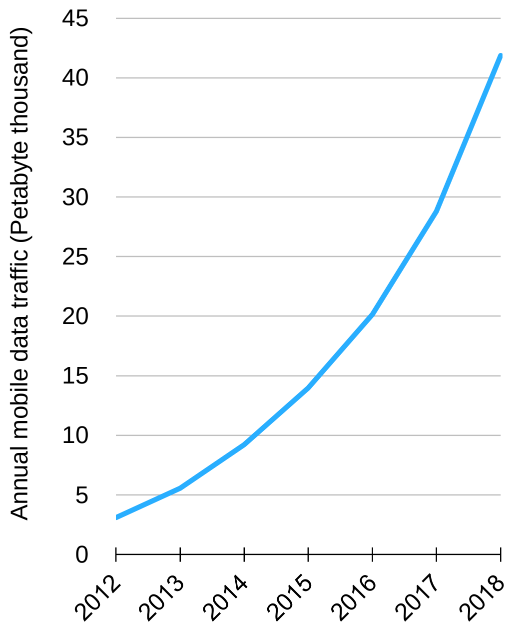


Figure 1.2: Historical and forecast (2014–18) Asia–Pacific annual data traffic [Source: Analysys Mason, 2014]

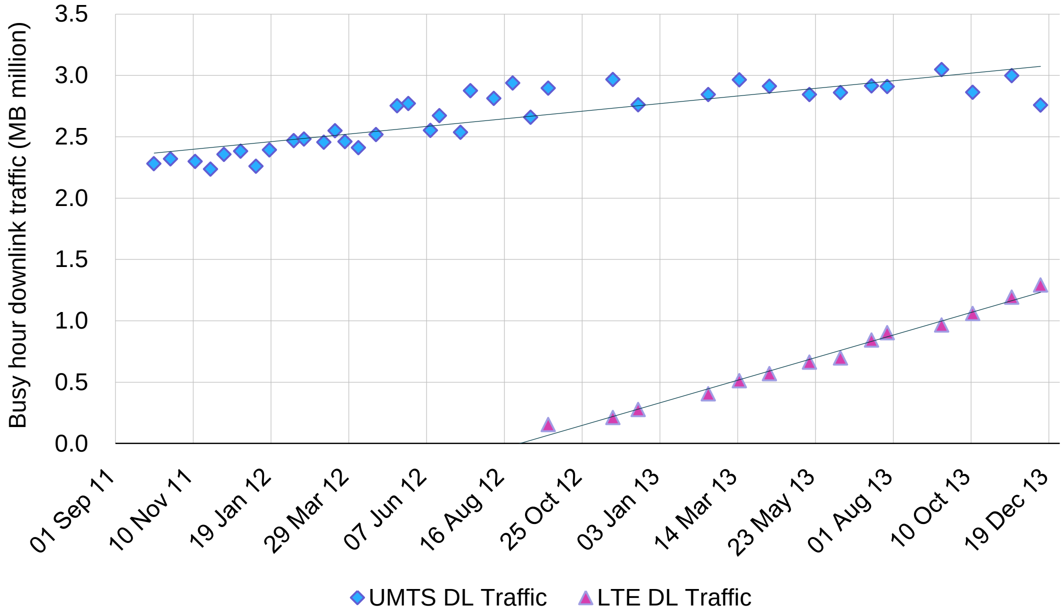


In terms of how traffic carried by 4G networks will evolve compared to 3G, estimations from Huawei are that LTE traffic carried over 4G networks typically exceeds UMTS traffic on 3G networks when LTE device penetration in a given network or country reaches 30%, which typically occurs two years after LTE deployment[2]. However, although 3G-to-4G migration is already under way in many countries, network statistics collected by Huawei suggest that total 3G traffic levels appear to be remaining stable, indicating that the remaining 3G users are increasing their data consumption.

For example, within one mobile network studied by Huawei, there has been an estimated increase of more than 22% in UMTS downlink traffic per 3G subscriber one year after the operator launched LTE. In the same network, downlink speed has improved by over 25% (average per user). The trend in UMTS downlink traffic, compared to LTE downlink traffic, within that mobile operator's 3G and 4G networks is illustrated below.

2 LTE is Long Term Evolution and is the industry standard for 4G; UMTS is the Universal Mobile Telecommunications System, which is a standardised technology for 3G adopted around the world.

Figure 1.3: UMTS and LTE traffic trend within one network in the Asia–Pacific region [Source: Huawei, 2014]



As well as growth in consumers' use of mobile broadband services, market trends suggest an increased growth in particular *types* of mobile data in the medium to long term, such as machine-to-machine (M2M) communications used by various industries (e.g. in the automotive, healthcare and transport sectors). With substantial growth in M2M connections being predicted, it follows that the number of device types connecting to mobile networks will increase substantially, and device types and traffic loads will become increasingly varied. These trends are leading towards the realisation of an Internet of Things that can exploit the increasing sophistication of devices, and respond to changing social and industrial trends.

1.3 Socio-economic benefits of mobile broadband

A number of previously published empirical studies support the conclusion that broadband services delivered over networks of all types – including wireless and mobile – can have a substantial positive impact on socio-economic development. Furthermore, as operators invest in deploying more infrastructure this also tends to exhibit spill-over effects, and thus the impact on the wider economy and the associated societal impact can be far-reaching, improving productivity, fuelling innovation and driving the creation of new businesses as well as providing improved access to personalised healthcare, online services and facilitating smart cities.

As few empirical studies exist that investigate the socio-economic impact of *mobile* broadband specifically, we have estimated the impact of *total broadband* connections penetration on economic prosperity. We define 'broadband' to include both fixed and mobile broadband connections, including the use of smartphones for data, but excluding basic mobile handsets.[3]

[3] Previous studies investigating the impact of broadband on the economy may not be comparable with the current study due to differences in the definition of broadband penetration (e.g. the difference between broadband penetration and broadband connections penetration, the latter exhibiting diminishing returns as users get more than one broadband connection), differences in technology mix, as well as differences in penetration forecasts.

Using a multiplier approach, we have estimated that a 10 percentage point increase in broadband connections penetration leads to between 0.26% and 0.92% increase in gross domestic product (GDP). It is reasonable to assume that in more developed countries more people are connected so the marginal impact of increased connectivity diminishes, which indeed is reflected in the GDP multipliers derived from previous scientific studies for developed and developing economies[4]. In short the former tend to experience a lower impact of increased connectivity than the latter as the dramatic shift of bridging the broadband divide has already happened. It may be noted, however, that further expansion of broadband can still bring significant value to advanced economies, should suitably accommodating policies be adopted by governments.

In terms of jobs created, and based on consensus data points from published studies, our estimations indicate that the addition of 1000 new broadband connections results in the creation of up to 33 new jobs. Initially new jobs are created as a result of *direct* effects related, for example, to the construction of new infrastructure. As these direct effects diminish, jobs are created as a result of *indirect* and *induced* effects, often in industries outside telecommunications (for example, industries that make use of broadband networks).

Within the countries studied within the Asia–Pacific region[5], this potentially gives rise to the impacts summarised in Figure 1.4 below, based on Analysys Mason's calculation.[6]

Figure 1.4: Cumulative impact on GDP and jobs resulting from increased broadband connections penetration in selected Asia–Pacific countries [Source: Analysys Mason, 2014]

	Country	ICT maturity	Δ broadband connections penetration (percentage points) (2013-20)	Cumulative GDP increment (USD billion)	Cumulative new jobs added (thousand)
Emerging	China	4.18	43	855	19 321
	India	2.21	35	290	14 722
Developed	Australia	7.90	37	11	287
	Hong Kong	7.92	61	7	146
	Singapore	7.65	43	5	80
	South Korea	8.57	36	17	593
	Total	**N/A**	**N/A**	**1185**	**35 149**

The role and impact of *mobile* broadband services compared to broadband connectivity as a whole varies within different markets, depending on the level of fixed-network investment and different consumer preferences (e.g. the extent to which substitution occurs between fixed and mobile

4 We have distinguished between developed and developing nations for our calculation based on their ICT Index.

5 We refer here only to the following specific countries – Australia, China, Hong Kong, India, Singapore and South Korea.

6 Since the level of benefits occurring depends on the level of penetration and ICT development within the country, we have considered ICT maturity based the published ICT Development Index for different countries.

services). We believe that, in the countries studied in this report, a significant proportion of the benefits stated above will be coming from mobile broadband. This impact is maximised if sufficient spectrum is available to enable mobile networks to be deployed with the best speeds and coverage achievable for the given market.[7]

1.4 How mobile technology is evolving

With substantial increases in the number of mobile connections – and traffic per connection – likely in the future, mobile technology and the way that mobile operators use spectrum are continually evolving.

Operators are investing to improve the speed and coverage of their 3G networks and to relieve congestion in UMTS2100 networks – for example, through deployment of UMTS900 and the addition of various UMTS capability-enhancing features such as dual-carrier UMTS for improved data carriage, and adaptive multi-rate (AMR) technology for improved voice quality. UMTS900 in particular has seen swift adoption, and is a key technology to relieve congestion within UMTS2100 networks as well as being used to improve coverage of 3G services through use of lower frequency spectrum. Huawei has estimated that the penetration of UMTS900 terminals has reached 80% in many Asia–Pacific markets, and also that around 25% of 3G devices used in Singapore support dual-carrier UMTS. Operators in the Asia–Pacific region are world leaders in terms of UMTS900 deployment with re-farmed 900MHz spectrum playing a key role in improving 3G capacity and coverage in countries such as Hong Kong, where mobile operator Hutchison successfully bid for 900MHz spectrum through an auction of mobile spectrum, in order to deploy UMTS900 in urban areas to relieve congestion within its UMTS2100 network, absorb heavy 3G data traffic and improve the customer experience from 3G services.

With the technological advances now being implemented in 4G through the deployment of LTE-A, average download speeds within 4G networks are continually increasing, which is expected to further drive the take-up of mobile broadband services as consumers obtain a mobile service with faster speeds and better quality.

The most recent releases of the LTE standard that incorporate LTE-A (i.e. releases 10, 11 and 12) are starting to have a significant impact on the way that operators use and manage 4G spectrum, since these incorporate both intra- and inter-band carrier aggregation (CA).[8] The benefits of CA are highest in markets where operators have multiple spectrum bands assigned to them, giving them the flexibility and the physical bandwidth required to implement advanced CA technologies.

7 The order of magnitude of these estimates is broadly consistent with other studies that the GSMA have published on the impact of mobile broadband services, where other studies have used a similar approach. Differences between Analysys Mason's estimates and other published GSMA study results are primarily due to different fixed and mobile penetration estimates being used to estimate the impact. It was not within the scope of this study to validate the penetration forecasts used in other published work.

8 The initial standard supported CA in specific bands only; subsequent releases (i.e. release 11 and release 12) have expanded the range of bands that are supported by inter-band CA as well as extending the scope for intra-band CA (e.g. from two 20MHz carriers, to three or more).

Operators in the Asia–Pacific region are at the forefront of LTE-A CA developments, and there are a range of networks across the region where LTE-A CA technology is being deployed, providing data speeds of 250–300Mbit/s and beyond.[9] In laboratory trials one operator – NTT DoCoMo – has achieved peak download speeds of over 1Gbit/s using LTE-A (by aggregating five 20MHz carriers). Future iterations of LTE-A (once these are supported in devices) will potentially enable peak downlink speeds up to 3Gbit/s to be provided, also by aggregating five 20MHz carriers, along with 8×8MIMO[10].

As well as supporting aggregation of multiple carriers, LTE networks in the Asia–Pacific region are also at the forefront of other 4G developments, such as voice over LTE (VoLTE). Although VoLTE technology has not been widely deployed around the world to date, a number of Asia–Pacific operators have launched VoLTE, in Hong Kong, Japan, Singapore and South Korea.

Implementation of LTE broadcast technology – Enhanced Multimedia Broadcast Multicast Service (eMBMS) – is an example of how mobile networks are evolving to support a wider range of services. For example, Huawei and China Telecom have deployed LTE-based eMBMS to distribute TV channels in Nanjing. Starting with the International Exhibition Centre used to host the 2014 Youth Olympic Games, coverage has been extended to over 30 base stations in Nanjing, including university and college campuses as well as the freeway between the International Exhibition Centre and the airport.

Neither 2G nor 3G networks have been able to support live video streaming economically, or with an acceptable user experience, but 4G networks are beginning to play a major role in making IP-based video streaming and multimedia services available to a large number of users. Various factors are combining to make live video streaming over LTE achievable:

- technological improvements such as caching third-party content locally on base stations, and video optimisation using innovative technology in the LTE Evolved Packet Core (EPC)
- advances in device technologies
- new features of LTE-A technology (e.g. carrier aggregation).

The advances in technology that are being implemented through LTE and LTE-A go some way to increasing network capacity and will also significantly improve on network speed and quality. However, it is recognised that operators will require access to significant additional spectrum to fully meet future market demands, both to cater for increasing demand for services, and to deploy higher-speed networks, which needs more spectrum to be available per operator to achieve the planned 100MHz (five times 20MHz) LTE-A CA supported by the latest industry standards.

9 LTE-A with carrier aggregation typically refers to technology based on 3GPP Release 10 and beyond

10 Source: Huawei

1.5 Spectrum implications

Based on market trends such as those identified in this report, previous research published by GSMA found that on average in each country a total of 1600–1800MHz of spectrum will be required for mobile services by 2020.[11] Similarly, the ITU has predicted that, on average, a total of between 1340 MHz and 1960MHz will be required for IMT/mobile broadband services by 2020.[12] This total includes spectrum already assigned for 2G, 3G and 4G which, as discussed in this report, is vital to support existing GSM, CDMA and HSPA services as well as emerging LTE and LTE-A network deployment.

The precise spectrum requirements vary for each nation. To provide an indication of the spectrum requirements in different markets, we have reviewed the spectrum currently used for provision of mobile services in eight Asia–Pacific countries, including developed and developing economies. We have found that the total amount of spectrum assigned – for all mobile operators in a given market, and for all generations of mobile technology – does not exceed 658MHz in any of the countries assessed. In some countries (e.g. China, India, Indonesia and Thailand), the amount of spectrum is significantly below this, despite mobile penetration forecasts and traffic predictions being high. This therefore leaves a significant shortfall between current levels of assigned spectrum and the GSMA's forecast requirement.

1.6 Implications

The GSMA has identified four frequency ranges that the mobile industry considers to be suitable for future use by mobile broadband services:

- sub-700MHz UHF (470–694MHz)
- L-Band (1350–1400 and 1427–1518MHz)
- 2.7–2.9 GHz
- C-Band (3.4–3.8 GHz and 3.8–4.2 GHz).

Our assessment of the current uses of each of these bands within selected countries in the Asia–Pacific region suggests that allocations within the bands are broadly similar between countries; however, the actual usage, and how extensively they are used, varies.

11 See http://www.gsma.com/spectrum/resources/, GSMA Public Policy Position: Mobile spectrum requirements and candidate bands for WRC-15

12 http://www.itu.int/en/ITU-R/study-groups/rcpm/Pages/default.aspx

Figure 1.5: Summary of candidate band allocation in the benchmark countries [Source: Analysys Mason, Frequency allocation tables, 2014]

	470–694/8MHz	1350-1400 and 1427-1518MHz	2.7–2.9GHz	3.4-3.8GHz and 3.8-4.2GHz
Australia	Fixed, Mobile, Broadcasting	Broadcasting, Broadcasting-satellite, Fixed, Mobile	Radionavigation, Radiolocation	Fixed, Mobile, Radiolocation, Amateur, Fixed–satellite
China	Broadcasting, Fixed, Mobile, Radionavigation, Radiolocation	Fixed, Mobile, Broadcasting, Broadcasting-satellite	Radionavigation, Radiolocation	Fixed, Mobile, Radiolocation, Amateur, Fixed–satellite
India	Fixed, Mobile, Broadcasting, Radionavigation	Fixed, Mobile, Broadcasting, Broadcasting-satellite	Radionavigation, Radiolocation	Fixed, Mobile, Radiolocation, Amateur, Fixed–satellite
Indonesia	Fixed, Mobile, Broadcasting, Radionavigation	Fixed, Mobile, Broadcasting, Broadcasting-satellite	Radionavigation, Radiolocation	Fixed, Mobile, Radiolocation, Amateur, Fixed–satellite
Japan	Fixed, Broadcasting, Mobile	Fixed, Mobile	Radionavigation, Radiolocation	Fixed, Mobile, Fixed–satellite
South Korea	Broadcasting	Fixed, Mobile, Radiolocation	Radiolocation	Fixed, Mobile, Radiolocation, Fixed–satellite
Thailand	Broadcasting, Fixed, Mobile	Fixed, Mobile, Broadcasting, Broadcasting-satellite	Radionavigation, Radiolocation	Fixed–satellite, Fixed, Mobile, Radiolocation, Amateur
Vietnam	Broadcasting, Fixed, Mobile, Radionavigation	Fixed, Broadcasting, Broadcasting-satellite, Mobile	Radionavigation, Radiolocation	Fixed–satellite, Fixed, Mobile, Radiolocation, Amateur

KEY: Fixed; Mobile; Broadcasting; Fixed–satellite; Radionavigation; Radiolocation; Amateur; Broadcasting-satellite

In considering how to meet future mobile spectrum needs, national regulators and policy makers face difficult choices when trying to make spectrum available for mobile use whilst also protecting existing service needs. Various options are open to achieve a better use of spectrum, enabling re-allocation of portions of bands to occur – for example, by concentrating existing services into particular sub-bands, deploying new technologies that require less spectrum, making use of alternative bands for existing services. Ultimately these choices should be guided by the benefits from the use of different bands for new mobile use, relative to the costs of alternative options to meet existing users' needs.

A key requirement from the mobile industry's perspective is that, as with previous bands identified for IMT use, additional spectrum needed to support future IMT services must be identified, as far as possible, at a global level, to avoid fragmentation between regions. Once identified at a global level, further harmonisation also needs to take place at a regional level so that countries in the Asia–Pacific region implement new mobile spectrum bands in a coherent way across different markets. Since the current spectrum landscape for 2G/3G/4G within the region is somewhat fragmented, it is important that policy makers work together to achieve a more consistent framework in future in relation to the way that different mobile bands are deployed and used.

As a complement to these approaches, we expect that more advanced approaches to spectrum sharing will be explored including approaches such as licensed shared access (now being considered at a European level); the gradual take-up of small-cell layers, with their reduced output power and the exploitation of higher frequencies (offering higher radio frequency signal attenuation), which will facilitate future exploitation of sharing opportunities as well as improvement in overall spectrum utilisation.

2 Introduction

This report is from a study that Analysys Mason has conducted for the GSM Association (GSMA) and Huawei on the socio-economic impact of mobile broadband services, and the measures needed at the forthcoming World Radio Conference in 2015 (WRC-15) to ensure that sufficient spectrum is available to facilitate further growth and development in the mobile market in the Asia–Pacific region.

2.1 Background and objectives of the study

Many studies conducted in recent years have highlighted the economic impact of decisions made by national governments about the award of mobile spectrum. This impact is substantial, due to the significant reliance on mobile networks – and mobile broadband services in particular – in today's society, both by consumers and businesses.

In response to market need, and to relieve congestion within their networks, mobile network operators (MNOs) are changing the way they use the spectrum assigned to them, as well as investing in new technologies. UMTSA900 has seen swift adoption by the market, for example, and is essential to improve coverage and relief congestion in UMTS2100 networks. Alongside continuing investments in 3G such as these, operators are now rolling out 4G and – in the Asia–Pacific region in particular – making use of the latest LTE-Advanced (LTE-A) technologies to combine multiple bands together through carrier aggregation (CA) and thereby maximise network throughput.

The advances in technology that are being implemented through LTE and LTE-A go some way to increasing network capacity, and will also significantly improve on network speed and quality. Despite these advances, it is recognised that operators will require access to significant additional spectrum to fully meet future market demands, both to cater for increasing demand for services, and to deploy higher-speed networks using the latest advances in LTE-A technology.

Accordingly, there is immense concern among the mobile industry that sufficient amounts of suitable radio spectrum may not be available in the future. WRC-15, organised by the International Telecommunications Union (ITU), will make vital decisions on the bands that will be assigned for future mobile use, and will identify specific portions of these bands for use by international mobile telecommunications (IMT). These decisions will be of great importance for the continued development of the mobile market in The Asia–Pacific region and globally, and are therefore subject to considerable debate in the industry, ahead of WRC-15.

With this in mind, Analysys Mason was commissioned by the GSMA to conduct this study, with supporting global analysis provided by Huawei. The aims of the study were as follows:

- Estimate the economic benefits that can be expected from increasing penetration of mobile broadband. This analysis is supported with case studies highlighting the benefits in six Asia–Pacific countries (China, Australia, Hong Kong, South Korea, India and Singapore).
- Analyse how MNOs are changing the way they use spectrum to adapt to market needs and to exploit the latest technologies.
- Describe the new services that are being offered as a result of developments in mobile technology.
- Examine the incumbent uses of the bands that the GSMA has identified as candidates for future mobile use in the selected countries, to be considered at WRC-15, and assess the scope for portions of these bands to be made available for mobile services.
- Identify key considerations for policy makers when considering the assignment of new spectrum for mobile use.

2.2 Structure of this document

The remainder of this document is laid out as follows:

- Section 3 describes key trends in the mobile market, focusing on the Asia–Pacific region and the six selected countries in particular.
- Section 4 discusses the impact of mobile broadband on society and national economies.
- Section 5 considers the need for additional spectrum.

The report includes a number of annexes containing supplementary material:

- Annex A contains case studies for China, Hong Kong, Singapore, India, Australia and South Korea.
- Annex B explains the methodology that this study has followed in order to estimate the benefits from mobile broadband services.

3 Key trends

3.1 Demand drivers in the mobile market

Mobile devices are increasingly viewed as an essential part of modern life. Recent years have seen a surge in mobile data traffic, and there is an expectation that mobile broadband use will continue to grow – an expectation that is borne out by Analysys Mason forecasts. Although the rate of growth in mobile *subscriber numbers* is slowing in some markets, the amount of *data traffic* carried by mobile networks is increasing, as individual subscribers on average consume more and more data.

Consumers are increasingly expecting to have access through their mobile devices to the same range of services that they can access via the fixed internet. Driven by this growing use of mobile devices to access the internet, it is predicted that there will be 3 billion mobile broadband (3G and 4G) connections in the Asia–Pacific region by 2020, consuming over 50 000 petabytes of data per year.

Some countries in the region are witnessing particularly strong growth in demand. In China, for example, the growth in mobile data subscribers and the increase in traffic per subscriber is expected to result in almost 15 000 petabytes of data being carried on Chinese mobile networks annually by 2019 – approximately 25% of the traffic forecasted for the entire Asia–Pacific region. This represents a compound annual growth rate (CAGR) of over 55% over the period 2014–19.

As well as growth in consumers' use of mobile broadband services, market trends suggest an increased growth in particular *types* of mobile data in the medium to long term, such as machine-to-machine (M2M) communications used by various industries (e.g. in the automotive, healthcare and transport sectors). With substantial growth in M2M connections being predicted, it follows that the number of device types connecting to mobile networks will increase substantially, and the types of devices and traffic loads will become increasingly varied. These trends are leading towards the realisation of an Internet of Things that can exploit the increasing sophistication of devices, and respond to changing social and industrial trends. In order to support the envisaged number of connections from mass-market M2M and the 'Internet of Things', it is important that mobile networks can offer more reliable network performance and lower latency, as well as more consistent speeds over wider areas.

The remainder of this section discusses these trends in more detail.

3.2 Growth forecasts

In recent years the rates of growth in mobile data subscriptions have significantly exceeded those of fixed data in many markets, and forecasts suggest that mobile data use will continue to grow. Globally, the number of mobile connections (excluding M2M) reached close to 7 billion in 2014, and is expected to continue to rise at a CAGR of 6% to reach over 8.5 billion in 2018, as shown in

Figure 3.1 below. This level of connections will equate to a mobile penetration of approximately 115% of the forecast world population of 7.5 billion.[13] Accompanying this growth in subscriber numbers there has been an even greater increase in global mobile data traffic, which is expected by Analysys Mason to grow at a CAGR of 42.5% for 2014–19 (and at an even greater rate of 47.1% for 2013–18).

Figure 3.1: Historical (2012-2014) and forecast (2014-2018) growth in mobile connections globally [Source: Analysys Mason, 2015]

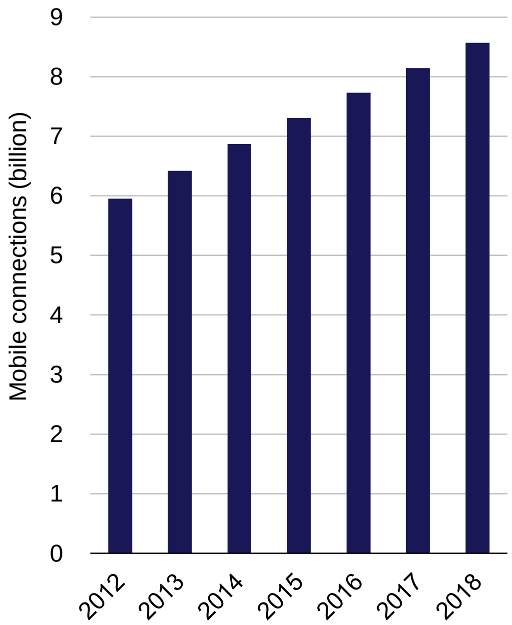
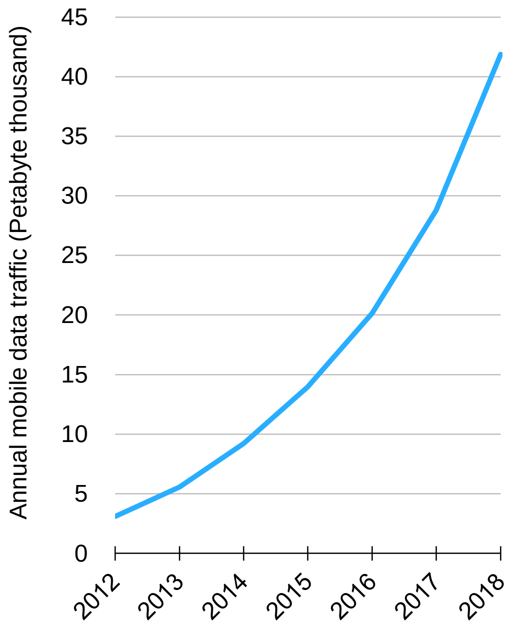


Figure 3.2: Historical (2012-2014) and forecast 92014-2018) growth in mobile data traffic globally [Source: Analysys Mason, 2015]



There are various different forecasts for how the number of mobile connections, and the traffic generated by mobile use, will grow; the variations between these forecasts highlight the inherent uncertainty in predicting longer-term market developments. In the charts above we have illustrated Analysys Mason's own forecasts of the growth in connections and traffic up to 2018; these forecasts are more conservative than some other estimates that have been published from other sources, such as those from Cisco, which are typically considered to be more optimistic.

As shown in Figure 3.3 and Figure 3.4, this global growth in mobile subscribers and data traffic is mirrored in the Asia–Pacific region, where Analysys Mason forecasts growth at rates of 6% for subscribers and 46% for traffic.

13 See http://www.geoba.se/population.php?pc=world&page=3&type=028&st=rank&asde=&year=2018

Figure 3.3: Historical(2012-2014) and forecast (2014-2018) growth in mobile connections in the Asia–Pacific region [Source: Analysys Mason, Cisco Visual Networking Index, 2014]

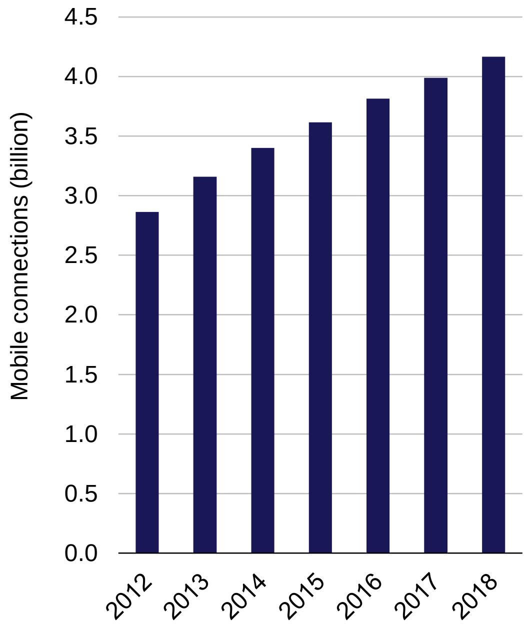
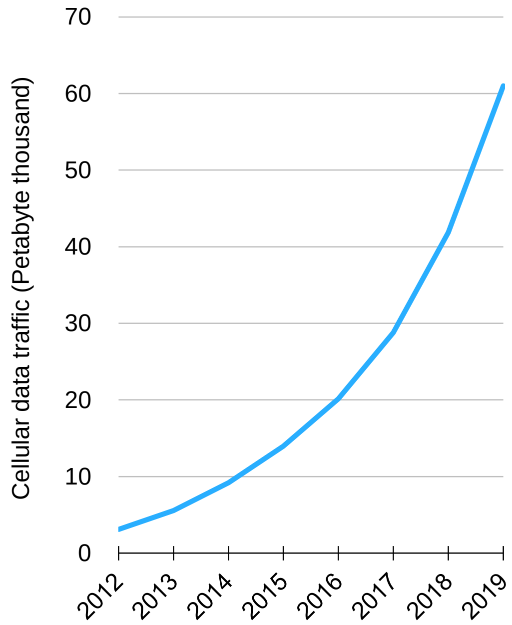


Figure 3.4: Historical (2012-2014) and forecast (2014-2018) growth in mobile data traffic in the Asia–Pacific region [Source: Analysys Mason, Cisco Visual Networking Index, ITU (ITU-R M.2243),[14] 2014]



Within the Asia–Pacific region there are significant differences in the demographic and economic status of countries, as demonstrated in Figure 3.5. These differences have influenced how mobile networks have developed in the different markets and, in particular, the rate of migration away from 2G to 3G/4G and the amounts of spectrum that are being deployed for mobile broadband (and 4G in particular).

Figure 3.5: Key demographic and economic indicators in study countries, 2013 [Source: Analysys Mason, World Bank, EIU, 2014]

	Population (million)	Population density (people per km^2)	GDP per capita (USD)
Australia	24	3	67 468
China	1356	145	6807
Hong Kong	7	6845	28 124
India	1256	421	1499
South Korea	51	516	25 977
Singapore	6	7713	55 182

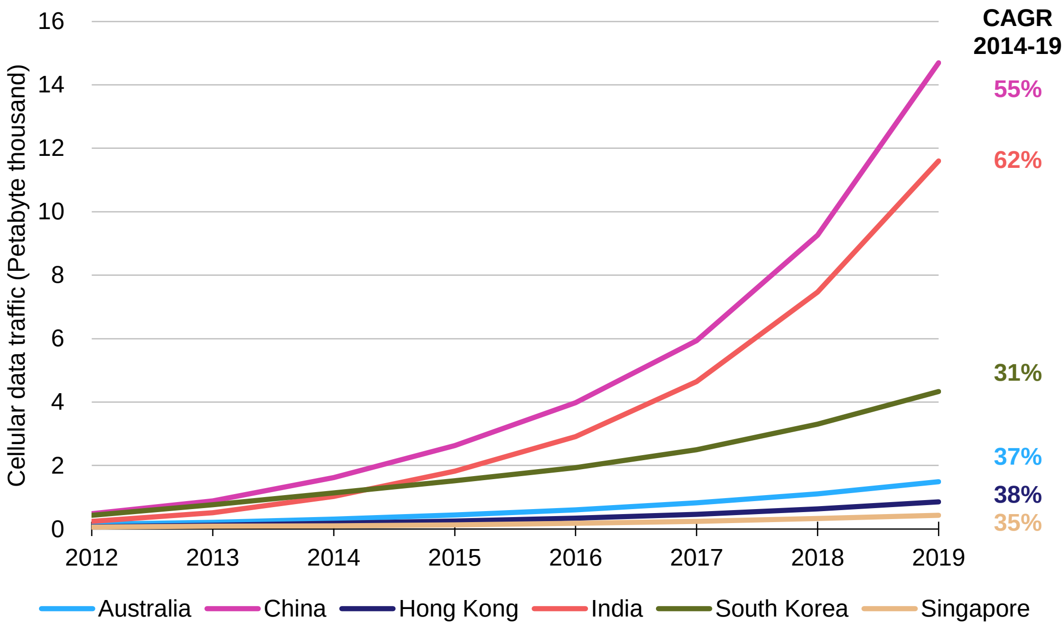
These underlying factors have affected the uptake and usage of mobile services, resulting in a range of subscriber and traffic volumes and in their forecast growth. The developed Asia–Pacific economies with GDP per capita of over USD25 000 all have a mobile penetration of over 100%

14 The ITU data series is constructed using three data points for 2012, 2015 and 2020.

and subscriber growth is slowing. In contrast, in China and India, penetration rates are forecast to continue to grow rapidly at CAGRs of 4.9% and 6.3% respectively.

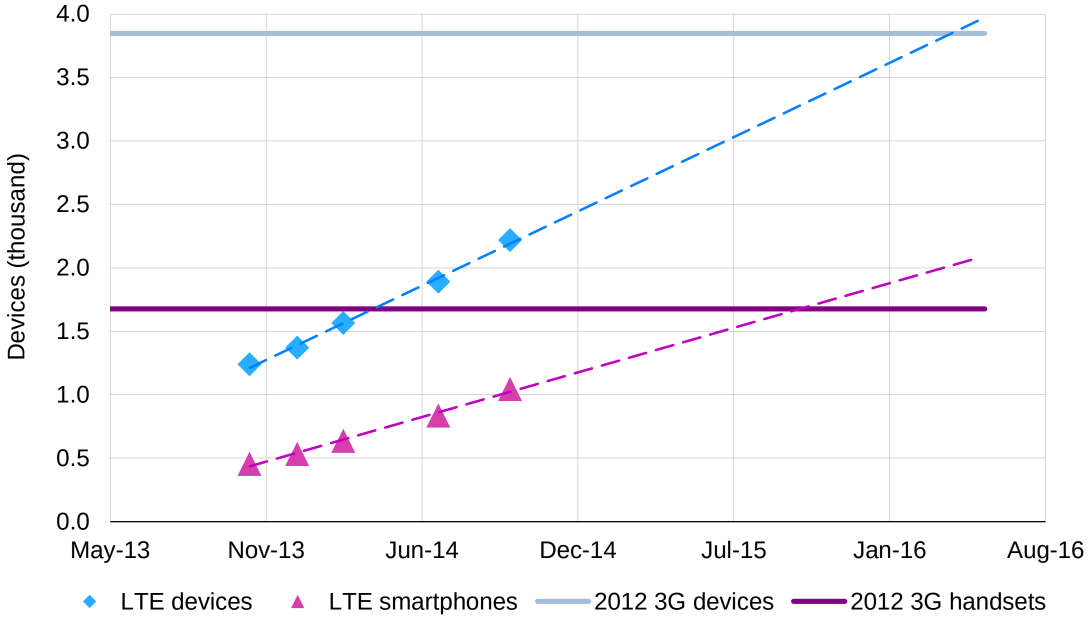
This difference in the rates of growth between most advanced Asia–Pacific economies and emerging economies continues to be very marked when mobile data traffic is considered. The high populations in China and India, alongside significant investment in their still nascent mobile industries means that traffic originating from these countries is expected to reach 14 700 and 11 600 petabytes respectively in 2019. Saturation in device ownership in the more developed economies means that traffic growth will be slower, at between 31% and 38% between 2014 and 2019. This is illustrated below.

Figure 3.6: Historical (2012-2014) and forecast (2014-2019) growth in annual data traffic in study countries [Source: Analysys Mason, 2014]



The number of 4G smartphones available in the market place is already growing to match that of 3G, based on data published by the Global Suppliers Association (see Figure 3.7). This trend is expected to continue as more countries assign spectrum for 4G in some of the key bands identified at WRC-07 and WRC-12 (and, crucially in the Asia–Pacific region, in the 700MHz band).

Figure 3.7: Number of 4G smartphones worldwide [Source: Global Mobile Suppliers Association, 2014]

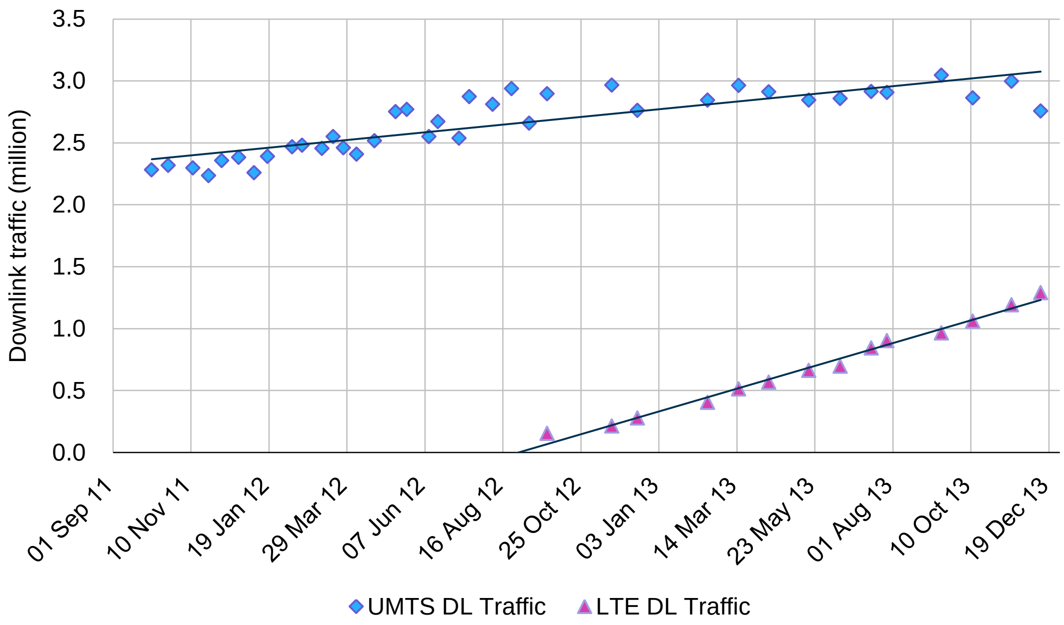


In terms of how traffic carried by 4G networks will evolve compared to 3G, estimations from Huawei are that LTE traffic typically exceeds UMTS traffic when LTE device penetration in a given network or country reaches 30%, which typically occurs two years after LTE deployment. However, although 3G to 4G migration is already under way in many countries, network statistics collected by Huawei suggest that total 3G traffic levels are remaining at a stable level. This indicates that the remaining 3G users are increasing their data consumption.

Within one mobile network in the Asia–Pacific region that Huawei studied, there has been an increase of more than 22% in UMTS downlink traffic per 3G subscriber one year after the operator launched LTE, from 1309 kbyte usage per month per 3G subscriber in 2012, to 1931 kbyte usage per month by the end of 2013. In the same network, UMTS downlink speed has improved by over 25% (average per user).

The trend in the total UMTS and LTE downlink traffic carried within this operator's networks is illustrated below, which shows that the rate of growth in 3G-traffic has been constant despite 3G to 4G migration starting once the operator launched an LTE network. This highlights, as described above that there has been an increase in downlink traffic per 3G user, since the operator launched 4G.

Figure 3.8: UMTS and LTE traffic trend within one network in the Asia–Pacific region [Source: Huawei, 2014]



3.3 How mobile technology is evolving

Compared to GSM and UMTS, LTE offers greater flexibility to operators in their efforts to accommodate the ever-rising levels of data traffic, as well as supporting higher speeds. Recent information published by the Global Mobile Suppliers Association suggests that there are well over 300 LTE networks now operational in 112 countries around the world.

LTE-A (the latest version of the LTE standard developed by 3GPP) will push the performance of 4G even further. With the technological advances being implemented within LTE-A, average download speeds within 4G networks are continually increasing, which is expected to further drive the take-up of mobile broadband services as consumers obtain a mobile service with faster speeds and better quality.

The most recent releases of the LTE standard that incorporate LTE-A (i.e. releases 10, 11 and 12) incorporate both intra- and inter-band CA,[15] as well as advanced antenna technology (i.e. multiple in, multiple out, or MIMO). Initial LTE-A deployments incorporating CA have used two carriers (e.g. bonding of 20MHz plus 20MHz carriers) to improve peak download speeds, but this is being extended to three or more carriers, across a wider range of bands and using higher orders of MIMO. Release 12 of the standard additionally supports FDD-TDD[16] carrier aggregation.

15 The initial standard supported CA in specific bands only; subsequent releases (i.e. releases 11 and 12) have expanded the range of bands that are supported by inter-band CA, as well as extending the scope for intra-band CA (e.g. from two 20MHz carriers, to three or more).

16 i..e. carrier aggregation between FDD and TDD deployment (using a combination of paired and unpaired spectrum).

Operators in the Asia-Pacific region are leading the world in the deployment of LTE-A. There are a range of networks across the region where LTE-A CA technology is being deployed, providing data speeds of 250–300Mbit/s and beyond. In laboratory trials one operator – NTT DoCoMo – has achieved peak download speeds of over 1Gbit/s using LTE-A (by aggregating five 20MHz carriers). Future iterations of LTE-A (once these are supported in devices) will potentially enable peak downlink speeds of up to 3Gbit/s; this is achieved by aggregating five 20MHz carriers, and employing 8×8MIMO.[17] Figure 3.9 provides details of a selection of actual and planned LTE roll-outs as well as trials, while Figure 3.10 shows the peak throughput achieved in lab tests using different carrier sizes.

Figure 3.9: Selected LTE-A test results in the Asia–Pacific region [Source: Global Suppliers Association, Analysys Mason, 2014]

Country	Operator	Maximum downlink speed
Australia	Telstra Optus	450Mbit/s (expected) 160Mbit/s (TD-LTE)
Hong Kong	CSL Limited	300Mbit/s (expected)
China	China Mobile China Telecom	233Mbit/s (TD-LTE) 160Mbit/s (FD-TD CA)*
Japan	NTT DoCoMo Softbank	300Mbit/s (expected) and 1.2Gbit/s (lab trial) 770Mbit/s (trial)
Philippines	Smart	210Mbit/s
New Zealand	Vodafone Spark	250Mbit/s (expected) 260Mbit/s (trial)
South Korea	SK Telecom LG Uplus KT	300Mbit/s (planned) 225Mbit/s 225Mbit/s
Singapore	M1 SingTel	300Mbit/s 300Mbit/s

* LTE-A with carrier aggregation typically refers to technology based on 3GPP Release 10 and beyond.

[17] Source: Huawei.

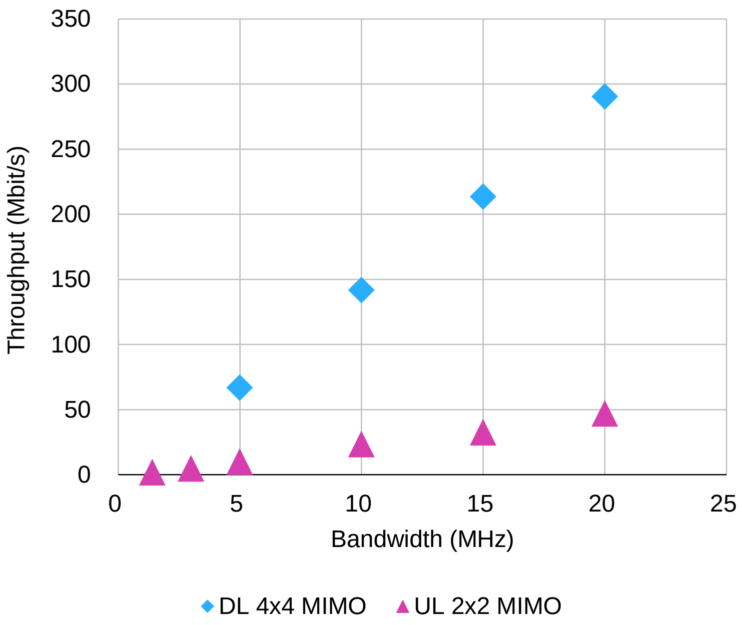


Figure 3.10: Peak throughput achieved in lab tests for different carrier sizes for LTE-A technologies [Source: Analysys Mason, Huawei, 2014]

LTE networks in the Asia–Pacific region are also at the forefront of other 4G developments, such as voice over LTE (VoLTE). Although VoLTE technology has not been widely deployed around the world to date, a number of Asia–Pacific operators have launched VoLTE services, including in Hong Kong, Japan, Singapore and South Korea.

Technological evolution is also enabling mobile networks to provide services such as high-quality streaming video. As the world becomes increasingly mobile, there is rising demand for access to services and content (including internet, social media and TV content) from any location, at any time. LTE broadcast technology (eMBMS or Enhanced Multimedia Broadcast Multicast Service) is one example of mobile networks' evolution to support a wider range of services. For example, Huawei and China Telecom have deployed LTE-based eMBMS to distribute TV channels in Nanjing. Starting with the International Exhibition Centre used to host the 2014 Youth Olympic Games, coverage has been extended to over 30 base stations in Nanjing, including university and college campuses as well as the freeway between the International Exhibition Centre and the airport.

The vast amount of video and multimedia content available on the fixed internet is driving similar expectations for access to on-line video services through mobile networks. More and more video content is being made available for on-demand streaming, including user-generated content through various services and sites such as YouTube. This directly leads to increasing demand to use mobile devices to access this content, and also to upload user-generated content whilst on the move, as well as to view live streamed content at sports events, concerts and other entertainment venues.

Neither 2G nor 3G networks have been able to support live video streaming economically, or with an acceptable user experience, but 4G networks are beginning to play a major role in making IP-based video streaming and multimedia services available to a large number of users. Various factors are combining to make live video streaming over LTE achievable:

- technological improvements such as caching third-party content locally on base stations, and video optimisation using innovative technology in the LTE Evolved Packet Core (EPC)
- advances in device technologies
- new features of LTE-A technology (e.g. carrier aggregation).

Video-optimisation technologies are already being tested and implemented within networks in the Asia–Pacific region. For example, Huawei is working with China Mobile to deploy technology to improve video experience through triple optimisation (video caching, transmission control protocol (TCP) optimisation, and smart pacing).[18] Other vendors have also recently begun testing products using systems that cache content locally on LTE base stations. One such system has been tested in the Singapore SportsHub, for example.[19]

The advances in technology that are being implemented through LTE and LTE-A go some way to increasing network capacity, and will also significantly improve network speed and quality. Despite these advances, it is recognised that operators will require access to significant additional spectrum to fully meet future market demands, both to cater for increasing demand for services, and to deploy higher-speed networks. More spectrum needs to be available per operator to achieve the planned 100MHz (i.e. involving the bonding of five 20MHz carriers)) LTE-A CA that is supported by the latest industry standards. These spectrum implications are explored further below.

3.4 How spectrum use is changing

With substantial increases in the number of mobile connections – and traffic per connection – likely in the future, as well as an increasing range of device types, the way that MNOs use spectrum is continually changing as mobile technologies evolve. Re-farming of 2G spectrum is a key trend that has been largely operator-driven in many markets: spectrum in the 800MHz, 900MHz and 1800MHz bands is proving to be very useful for 3G and 4G deployment, to complement 3G coverage provided using higher bands (e.g. 2100MHz) and also to provide additional 4G capacity (e.g. using the 1800MHz band). There is considerable market interest in re-farming 1800MHz spectrum for use by LTE networks, and 1800MHz remains the most popular band for 4G/LTE deployment globally, ahead of other bands such as 700/800MHz and 2.6GHz.

Operators are also using re-farmed 2G spectrum to improve the speed and coverage of their 3G networks and to relieve congestion in UMTS2100 networks – for example, through deployment of UMTS900 and the addition of various UMTS capability-enhancing features such as dual-carrier UMTS for improved data carriage, and adaptive multi-rate (AMR) technology for improved voice quality. UMTS900 in particular has seen swift adoption, and is a key technology to relieve

18 A technique used to reduce traffic carried over mobile networks, e.g. through buffering, to reduce the amount of bandwidth used.

19 See http://nextvasia.com/broadcast-related-technology/starhub-nokia-demonstrate-mobile-edge-video-delivery/

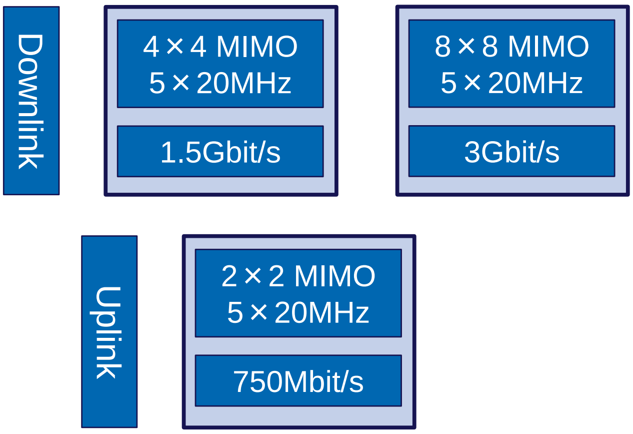
congestion within UMTS2100 networks; it is also being used to improve 3G coverage through the use of lower-frequency spectrum. Huawei has estimated that the penetration of UMTS900 terminals has reached 80% in many Asia–Pacific markets, and also that around 25% of 3G devices used in Singapore support dual-carrier UMTS. Operators in the Asia–Pacific region are world leaders in terms of UMTS900 deployment, and re-farmed 900MHz spectrum is playing a key role in improving 3G capacity and coverage in countries such as Hong Kong. Hutchison successfully bid for 900MHz spectrum in order to deploy UMTS900 in urban areas of Hong Kong to relieve congestion within its UMTS2100 network, absorb heavy 3G data traffic and improve the customer experience of 3G services.

The market has so far largely concentrated on UMTS900 (rather than LTE900), but this picture is changing rapidly. Operators in Singapore and Taiwan, for example, have now launched LTE900 networks.

Although there are many reasons for MNOs to migrate customers away from 2G networks, it should be noted that it is difficult for operators to switch off 2G networks completely. 2G networks continue to be important in many countries and the rate of migration away from 2G is highly dependent on local circumstances. 2G networks are particularly important for some categories of use – M2M, for example. In the Asia–Pacific region, the rate of migration away from 2G has been very swift in some countries – for example, Japan, Singapore and South Korea – while in other countries 2G networks still account for the majority of mobile connections, and are often seen as being crucial to cater for certain services such as voice, as well as to accommodate global roaming. Releases 10–12 of the LTE standard, which incorporate LTE-A, are starting to have a significant impact on the way that MNOs use and manage 4G spectrum, since these incorporate both intra- and inter-band CA, as well as advanced antenna technology (MIMO), as discussed in the previous section. Initial LTE-A CA deployments have used two carriers (e.g. bonding of two 20MHz carriers) to improve peak download speeds, but the extension to three or more carriers is on-going, across a wider range of bands, and using higher orders of MIMO.

The availability of larger contiguous blocks of spectrum therefore makes it possible for operators to move to more advanced technology releases, offering ever higher speeds to subscribers. For example, a move from 4×4MIMO to 8×8 MIMO results in a doubling of peak speeds (see Figure 3.13 below).

Figure 3.11: Evolution of peak theoretical downlink speeds [Source: Huawei, Analysys Mason, 2014]



Release 12 of the standard additionally supports FDD-TDD carrier aggregation. This is a major change to the way that MNOs have previously used spectrum, and enables multiple bands to be used in combination to offer higher throughputs. The benefits of this are therefore highest in markets where MNOs have multiple spectrum bands assigned to them, giving them the flexibility and the physical bandwidth required to implement advanced CA technologies.

4 The impact of mobile broadband connectivity on society and the economy

4.1 Overview of the socio-economic benefits of broadband services

Broadband services delivered over networks of all types – including wireless and mobile – are widely acknowledged to generate a significant range of socio-economic benefits within both developed and emerging markets. As an infrastructure investment, broadband networks tend to exhibit spill-over effects and their role as an engine for the economy can be far-reaching – improving productivity, fuelling innovation and creating new businesses. Beyond economic impact, the wider societal benefits derived from broadband services – such as improved access to healthcare, education, government services, etc. – play an important role in promoting development, bridging the digital divide and laying the foundations of knowledge-based societies.

As few scientific papers exist investigating the impact of *mobile* broadband specifically, we have estimated the impact of *total broadband* penetration on economic prosperity in the six countries under study (Australia, China, Hong Kong, India, Singapore and South Korea). In this context, we define ‘broadband’ to include both fixed and mobile broadband connections, including the use of smartphones for data, but excluding basic mobile handsets.[20]

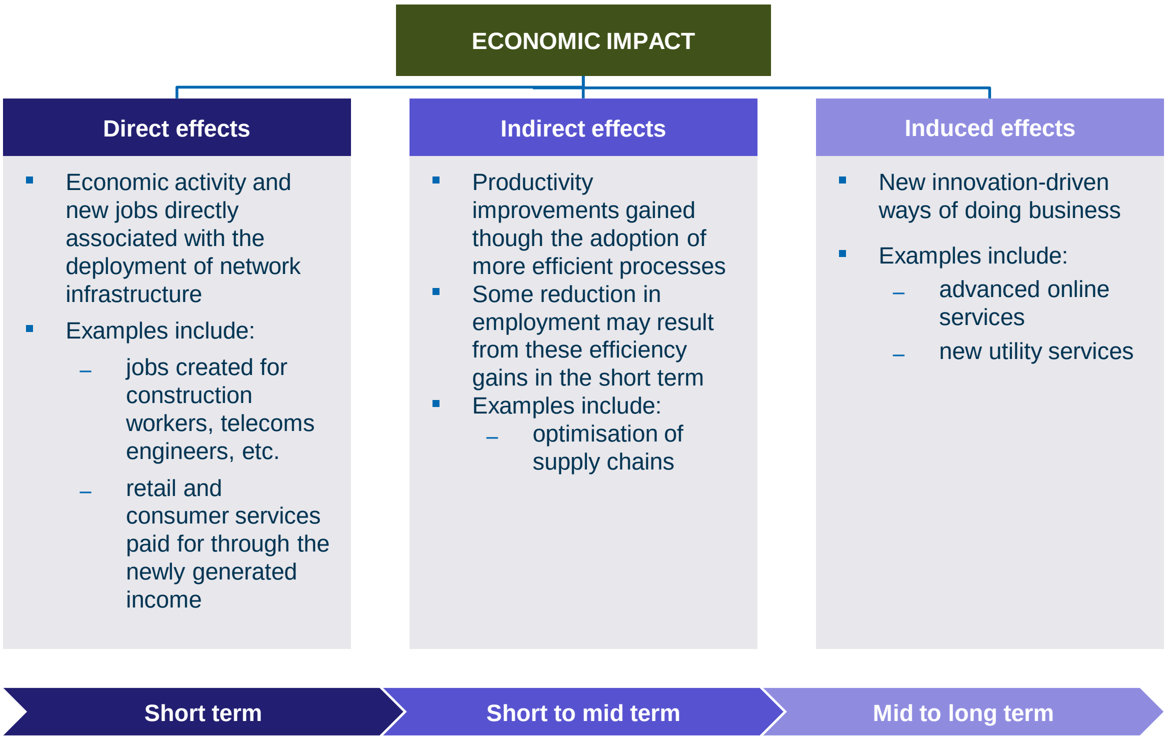
Economic impact

There are three main routes through which broadband infrastructure and services have an effect on the economy:

- *Direct effects* are usually short-term effects and are related to the deployment of infrastructure, i.e. construction works as well as other associated economic activities.
- *Indirect effects* concern improvements in productivity and efficiency that are possible as new technologies allow faster and more optimised processes.
- *Induced effects* occur in the long term as new innovations and ideas diffuse throughout society, creating a conductive environment for new services and business models to arise.

[20] Previous studies investigating the impact of broadband on the economy may not be directly comparable with the current study due to differences in the definition of broadband penetration, differences in technology mix, as well as differences in penetration forecasts.

Figure 4.1: Economic impact of broadband [Source: Analysys Mason, 2014]

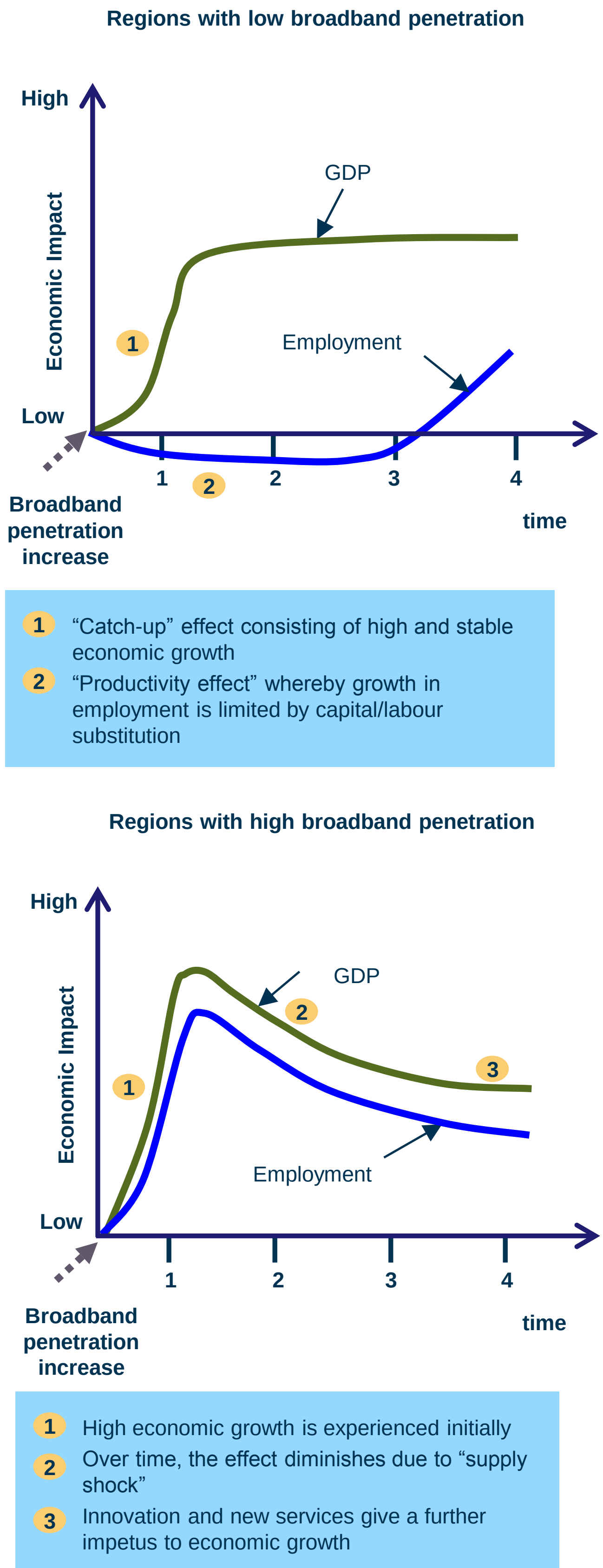


The magnitude of the effects depends on the level of ICT development. The use of telecoms services by a subscriber creates positive externalities and increases their intrinsic value, so that as the number of connected users increases, the value of the network also increases. Until the last 20 years, telephone connections between users in the Asia-Pacific region were relatively few in number, meaning that they did not yield significant economic benefits. As telecoms infrastructure developed, more and more users were connected, increasing the value of the network. Nowadays a large number of people are connected, significantly increasing the benefit of the network and raising the cost of remaining outside it.

Numerous studies point to increasing returns stemming from broadband investments at higher levels of broadband penetration and ICT development. However, as countries reach a certain level of ICT maturity, the incremental benefits from further investments tend to diminish as productivity and efficiency gains become more difficult to realise. At this point renewed growth may be realized through innovation and new services, if accommodating policies are adopted by governments.

Depending on the level of ICT maturity, the effects of broadband penetration on output and employment may not be synchronized. In regions with *low* broadband penetration the ‘productivity effect’ may hinder employment growth due to capital/labour substitution. In contrast, in regions with *high* broadband penetration, output and employment may follow another pattern – high initial economic growth, followed by diminishing returns and, potentially, a later phase of renewed growth. These patterns are illustrated in Figure 4.2 below.

Figure 4.2: Impact of broadband penetration on GDP and employment [Source: Katz, R. et al (2010); Analysys Mason, 2014]



Quantifying economic impact

There are a number of interrelated effects which result from broadband investments, and these interdependencies do not allow for a simple sum of effects to be calculated, as the total impact may be estimated incorrectly due to double counting. Thus quantifying the economic impact of broadband proves to be a complex process.

Three main methods are used in estimating the impact of broadband infrastructure investments on economic prosperity: multivariate regression modelling, input/output analysis and cost–benefit analysis. We have used a fourth method – the *multiplier approach* – which derives estimates based on a consensus of the results obtained by previous studies. We selected this method as it enables us to take advantage of the results obtained by studies using the three other methodologies; it also offers a wide perspective and is relatively easy to understand. As the approach depends upon the quality of the existing scientific papers and business reports being considered, we have gone through a rigorous filtering and quality-control process.

The filtered data points were used to derive GDP and jobs multipliers. Following this, utilising forecasts of broadband connections penetration from Analysys Mason Research, as well as economic and demographic indicators, we built a generic model for each of the countries of interest in the Asia–Pacific region. The model allows us to estimate the impact of increased broadband connections penetration on output and jobs.

Details of the methodology we have followed can be found in Annex B.

4.2 Impact on GDP

Using the multiplier approach, we have estimated that a 10 percentage point increase in broadband connections penetration leads to between 0.26% and 0.92% increase in output. Consistent with the diminishing marginal returns theory, there is a difference between the GDP impact for developed and developing nations – the former tend to experience a lower impact (0.26%) compared to the latter (0.92%). It is reasonable to assume that in developed countries the dramatic shift of bridging the broadband divide has already happened and more people are connected, so the marginal impact of increased connectivity diminishes over time.

What this means in the Asia–Pacific region is that by 2020, the increase in broadband connections penetration – including mobile broadband – could lead to a cumulative GDP increment of USD1.2 trillion for the six countries studied. Benefits are likely to arise both from 'connecting the unconnected' as well as from improving efficiency and productivity though having additional connections.

The greatest benefits are expected to be reaped by China and India, because of the size of their economies and their lower level of ICT development: by 2020, China could add a cumulative increment of USD855 billion to its GDP, and India USD290 billion. In the advanced Asia–Pacific region countries studied, the cumulative contribution that increased broadband connections penetration will make to GDP is estimated to reach USD5–17 billion by 2020. Although the impact on these advanced economies is lower, broadband can still bring significant value and foster the growth of new businesses in the knowledge-based economy. .

Figure 4.3: Cumulative impact on GDP and new jobs resulting from increased broadband connections penetration in study countries over the period 2014–20 [Source: Analysys Mason, 2014]

	Country	ICT maturity	Δ broadband connections penetration (2013–20)	Cumulative GDP increment (USD billion)	Cumulative new jobs added (thousand)
Emerging	China	7.9	43	855	19 321
	India	4.18	35	290	14 722
Developed	Australia	7.92	37	11	287
	Hong Kong	2.21	61	7	146
	Singapore	7.65	43	5	80
	South Korea	8.57	36	17	593
	Total	**N/A**	**N/A**	**1185**	**35 149**

The role and impact of *mobile* broadband compared to broadband as a whole varies within different markets, depending on the level of fixed-network investment and local consumer preferences (e.g. the extent to which substitution occurs between fixed and mobile services). We believe a significant proportion of the benefits stated above will come from mobile broadband within the studied countries. This benefit will be maximised if sufficient spectrum is available to enable mobile networks to be deployed with the best speeds and coverage achievable for the given market.[21]

4.3 Jobs created

Based on consensus data points, our estimations indicate that the addition of 1000 new broadband connections results in the creation of up to 33 new jobs. Initially new jobs are created as a result of *direct* effects related, for example, to the construction of new infrastructure. As these direct effects diminish, jobs are created as a result of *indirect* and *induced* effects, mainly in other industries (for example, industries that make use of broadband networks).

In the period up to 2020 the Asia–Pacific region may add a total of up to 35 million jobs as a result of increasing broadband connections penetration. China and India are expected to experience the greatest impact in terms of job creation – cumulative totals of 19.3 million and 14.7 million new jobs, respectively. We estimate that each of the developed countries studied will add between

[21] The order of magnitude of these estimates is broadly consistent with other studies that the GSMA has published on the impact of broadband services, where those studies have used a similar approach. Differences between Analysys Mason’s estimates and certain other studies published by the GSMA are primarily due to different forecasts for fixed and mobile penetration being used to estimate the impact. It was not within the scope of this study to validate the penetration forecasts used in other published work.

80 000 and 593 000 jobs over the period, depending on the size of their economies and forecast broadband connections penetration.

4.4 Other impacts

Although difficult to quantify, social benefits constitute an important part of the overall value of broadband investments. Improved access to healthcare services, education and government services are among the areas where broadband may play an increasingly important role. Mobile health applications facilitate rapid diagnosis of critical conditions, improve access to specialised treatment, and act as a platform for remote monitoring and disease prevention. E-learning is becoming an important pillar in building knowledge-based societies and opening up education to everyone. It increases educational opportunities, acts as a platform for skill-building and promotes development in rural and remote areas. Broadband can improve economic opportunities in these areas and help bridge the digital divide through improving productivity, providing opportunities for non-agricultural jobs and fostering the growth of small and medium-sized businesses.

In addition, environmental effects may also be significant. For example, increased broadband connectivity would allow more people to work from home, reducing the need for commuting and business travel, thus decreasing carbon emissions. At the same time, smart electric systems are making big steps in increasing efficiency of energy consumption, and the shift towards cloud computing may deliver significant gains in energy efficiency.

A white paper published by Huawei[22] summarises a number of ways that societies will benefit from the different types of connection that mobile networks provide:

- People-to-people communications (e.g. remote healthcare, crowdsourcing) provide benefits through inclusiveness, and sharing of collective wisdom.
- Things-to-things communications (e.g. smart cities, interconnected smart devices) provide resource savings and logistical efficiencies, and can offer improvements in safety.
- People-to-things communications (e.g. intelligent health aids) provide benefits such as the ability to access personalised healthcare, and more and better services.

22 Huawei, *Building a better connected world*, available at www.huawei.com

5 The need for additional spectrum

5.1 Predicted spectrum needs

As set out in Section 3.2, mobile traffic is forecast to grow significantly, both globally and across the Asia–Pacific region. In order to serve this increasing demand, MNOs are investing in the development and deployment of new technologies and denser infrastructure. However, while these advances will go some way to increasing network capacity, in order to fully serve demand MNOs will require access to significant additional spectrum. Previous research published by the GSMA found that on average in each country a total of 1600–1800MHz of spectrum will be required for mobile telecoms by 2020. Similarly, the ITU has predicted that an average total of 1340–1960MHz will be required for IMT/mobile broadband services by 2020.

The precise spectrum requirements vary for each nation. In some countries, the population is more concentrated than in others, affecting the type and amount of spectrum needed to achieve mobile broadband coverage. In more densely populated countries, better efficiencies (both in terms of spectrum use and in the cost of rolling out networks) can be achieved using spectrum in higher frequency bands, although sub-1GHz spectrum is still beneficial in these countries to achieve the depth of coverage required for in-building smartphone use of mobile broadband services.

To provide an indication of the spectrum requirements in different markets, we have reviewed the spectrum currently used for the provision of mobile services in eight Asia–Pacific countries, including developed and developing economies. As shown in Figure 5.1, at the moment the total spectrum assigned – for all MNOs in the national market and for all generations of technology – does not exceed 658MHz in any of the eight countries. In some (e.g. China, India, Indonesia and Thailand), the amount of spectrum is significantly below this, despite mobile penetration forecasts and traffic predictions being high. This therefore leaves a significant shortfall between current levels and the GSMA’s 1600–1800MHz forecast requirement for 2020. The current levels also fall well below the forecast spectrum needs stated by the national regulators.

Figure 5.1: Summary of mobile spectrum use and shortfall from forecasted spectrum requirements in eight Asia–Pacific countries [Source: Analysys Mason, ITU, GSMA, national regulators' websites, 2014]

Country[23]	Bandwidth in use for mobile (2014)	Forecast of spectrum needs by national regulator	Shortfall from GSMA's spectrum target for 2020	Shortfall from local regulator's target
Australia	658MHz	1100MHz by 2020	942–1142MHz	442MHz
China	477MHz	570–690MHz in 2015; 1490–1810MHz by 2020	1123–1323MHz	93–213MHz in 2015; 1013–1333MHz by 2020
India	360MHz	Additional 300MHz by 2017; a further 200MHz by 2020	1240–1440MHz	300MHz by 2017; 500MHz by 2020
Indonesia	345.75MHz		1254.25–1454.25MHz	
Japan	546MHz	A further 1.2GHz by 2020	954-1154MHz	1.2GHz by 2020
South Korea	340MHz	Additional 1190MHz of spectrum by 2023	1240–1440MHz	1190MHz
Thailand	339MHz		1241–1441MHz	
Vietnam	340MHz		1240–1440MHz	

Of the spectrum currently in use for mobile service provision in the countries we have considered, only a sub-set is used for high-speed 3G and 4G mobile data/broadband services (the remainder being used for 2G services). We have considered how the amount of such spectrum compares to the number of 3G and 4G connections, both in 2014 and forecast for 2018. The spectrum considered is limited to bands and licences assigned to or re-farmed for 3G and 4G. Currently, 3G and 4G connections in the eight countries have an average of between 0.62MHz and 17.71MHz of spectrum each, depending on the country. However, if no further spectrum is licensed for 4G by 2018, these numbers will fall to between 0.33MHz and 14.38MHz per connection due to take-up of 3G and 4G services.

23 Japan and Australia are the only two countries in our benchmarks that have finalised reassigning the digital dividend spectrum (700MHz band) to mobile services, therefore we would expect an additional 2×30MHz of spectrum to be assigned to mobile in the remaining six countries when this process is completed

Figure 5.2: Analysis of deployed 3G and 4G spectrum and subscribers [Source: Analysys Mason, 2014]

	Total spectrum	2014		2018	
		3G and 4G connections (million)	**Spectrum per connection (Hz per connection)[24]**	**3G and 4G connections (thousand)**	**Spectrum per connection (Hz per connection)**
Australia	2×180MHz 98MHz TDD	27	17.71	33 398	14.38
China	2×65MHz 205MHz TDD	566	0.62	1055	0.33
India	2×40MHz 40MHz TDD	116	1.09	383	0.33
Indonesia	2×71.875MHz	132	1.14	217	0.69
Japan	2×216MHz 120MHz TDD	140	3.93	157	3.52
South Korea	2×160MHz	56	8.16	58	7.79
Thailand	2×70MHz 15MHz TDD	46	3.53	88	1.84
Vietnam	2×60MHz	26	4.76	49	2.56

Despite these national variations, it is important that allocations of mobile spectrum are made at an international level as far as possible, to foster global economies of scale. Accordingly, the ITU-R and the GSMA are striving to identify additional spectrum for IMT at a global level where possible (with the detailed assignment of these bands up to national regulators to implement based on national demand). The requirement for globally identified bands is therefore as important at WRC-15 as it has been in previous WRCs where spectrum requirements for IMT have been discussed.

5.2 Meeting predicted future needs

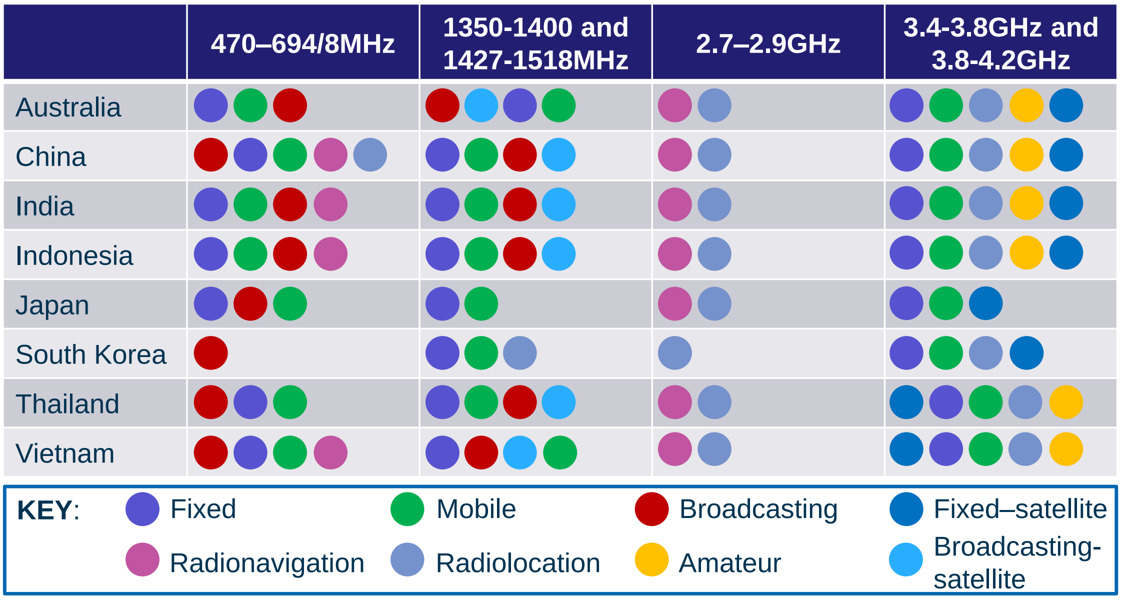
As input to the worldwide preparations for WRC-15, the GSMA has identified four frequency ranges it considers suitable for mobile use, in order to satisfy the forecast demand for mobile spectrum. The four candidate bands are as follows:

- sub-700MHz UHF (470–694MHz)
- L-Band (1350–1400 and 1427–1518MHz)
- 2.7–2.9 GHz
- C-Band (3.4–3.8 GHz and 3.8–4.2 GHz).

24 It is noted that Hertz per connection is not a meaningful figure in terms of precisely defining future spectrum needs since 3G and 4G networks use multiple access techniques such that individual frequency channels are not assigned exclusively to individual users. It is used here only as a comparison of the currently assigned mobile spectrum within the different countries profiled in this report.

These bands are considered by the GSMA to be credible options because they could be used in most markets across all three ITU Regions, thereby creating internationally harmonised spectrum. We have audited the spectrum band plans of eight countries in the Asia–Pacific region, and the current allocations for the candidate bands are shown in Figure 5.3 below. The candidate bands are allocated in broadly the same fashion across the benchmarked countries; however, their actual usage varies.

Figure 5.3: Summary of allocation of GSMA candidate bands in eight Asia–Pacific countries [Source: Analysys Mason based on national frequency allocation tables, 2014]



The APT Conference Preparatory Group is developing proposals to WRC-15 on behalf of regulators in the Asia–Pacific region, and has collated their preliminary views on the allocation of various spectrum bands between 470MHz and 39.5GHz to mobile. As shown in Figure 5.4, there is support for spectrum in the L-Band, 2.7-2.9GHz band and the C-Band for use by mobile services and IMT.

Candidate band	Countries stating support for use of band (or sub-band) for IMT
L-Band (1300–1518MHz)	Australia, Indonesia, Japan, new Zealand, South Korea, Vietnam
2.7–2.9GHz	Australia, Indonesia, Iran
C-Band (3.4–4.2GHz)	Australia, Iran, Japan, South Korea

*Figure 5.**4**: preliminary views of APT member countries on use of candidate bands for IMT [Source: Analysys Mason, APT, 2014]*

Further statements regarding the future use of the candidate bands have been released by regulators in a number of Asia–Pacific countries. Much of the discussion has focussed on the higher-frequency spectrum, and there has been little mention of sub-700MHz UHF spectrum within the countries we have profiled in this study, in part because in these countries the 700MHz band is yet to be fully assigned to mobile telecoms, and hence further consideration of UHF spectrum below 694MHz is premature. In four of these countries the digital switchover remains uncompleted.

Below we provide specific examples of initiatives from regulators in selected Asia–Pacific countries to address the likely shortfall for mobile spectrum:

- **Australia –** In May 2011, the Australian Communications and Media Authority (ACMA) identified parts of the L-band (1427.9–1462.9MHz and 1475.9–1510.9 MHz) and the 2.7–2.9GHz band as candidate bands for mobile broadband in its *Towards 2020* strategy. ACMA is planning conduct a review of the 1.5GHz band in 2015/2016 to consider potential future use of this band by mobile services. However, ACMA will consider the outcomes of the WRC-15 before progressing work domestically; it is possible that this will result in a move towards using the 1452–1492MHz band plan that has been discussed elsewhere in the region. The 3.4GHz band (3425–3575MHz) was auctioned for fixed wireless access in 2000, with licences due to expire in December 2015. In June 2014, ACMA released a consultation paper on possible future uses of the 3.4GHz band, which proposed a move towards use of this spectrum for fixed and mobile broadband services.

- **China –** Digital switchover is on-going in China: analogue channels are being switched off in batches, and although the first batch was switched off in January 2014, the final batch will remain in operation until January 2018. The spectrum to be released from the digital switchover has been identified for mobile use; a band plan has yet to be announced. In this regard, assignment of the 700MHz band in accordance with the harmonised APT band plan is under consideration. Additionally, although the Ministry of Industry and Information Technology has stated that it plans to use the lower C-band (3.4–3.6GHz) for mobile services, it has not yet set out a timeline for the transition. The intention is that radiolocation services currently using this spectrum will be moved to other bands and, though existing radio stations may continue to operate until the band is released for alternative use, new radio stations have been prohibited from operating in the band since 2005.

- **India –** The National Telecom Policy published by the Department of Telecommunications (DoT) in 2012 proposed a number of actions regarding further spectrum release to mobile services in order to support backhaul in rural areas. In particular, it contains proposals to make available for commercial mobile services adequate globally harmonised IMT spectrum in the 450MHz, 700MHz, 1800MHz, 1910MHz, 2.1GHz, 2.3GHz, 2.5GHz and 3.5GHz bands, as well as other bands to be identified by ITU. In total, 300MHz of additional spectrum is to be made available for IMT services by 2017, with a further 200MHz released by 2020. In 2012, the DoT launched a public consultation on further spectrum assignments to mobile services in the 700MHz, 1800MHz, 1910MHz and 2.1GHz bands, to coincide with the expiration of a number of 900MHz and 1800MHz licences in 2015/2016.

- **Indonesia** – The DSO will not be completed until 2018, and so far the regulator has not announced any plans to release spectrum for mobile use arising from DSO. It has, however, stated that it has no plans to move away from using the 3.4–3.6GHz band solely for fixed-satellite services. It is understood that plans are being confirmed to release a further 30MHz of spectrum in the 2.3GHz band for mobile wireless broadband use.

- **Japan –** The Ministry of Internal Affairs and Communications (MIC) published a spectrum plan in February 2010, which included a number of proposals to release new spectrum bands for mobile communications. The plan targeted a release of at least 300MHz of spectrum within the range 300–5000MHz by 2015, including the 72MHz of 'digital-dividend spectrum' that was assigned in 2012. By 2020, a cumulative total of at least 1500MHz across all spectrum bands will have been released. The MIC's proposed spectrum for assignment to mobile services included an additional 20MHz of spectrum in the L-band and the entire 200MHz of spectrum in the lower C-band (3.4–3.6GHz), to be assigned to mobile services by 2015. The spectrum to be assigned beyond 2015 is to be made up of 1.2GHz in the upper C-band (3.6–4.2GHz) and 4.4–5GHz bands (for the full 1.2GHz of spectrum to be available, all of the spectrum in both bands will need to be released). In December 2014, it was confirmed that 120MHz of unpaired spectrum in the 3.4-3.6GHz band had been assigned to the three largest mobile operators in Japan (DoCoMo, KDDI and SoftBank)[25]

- **South Korea –** The Ministry of Science, ICT & Future Planning in its *Mobile Gwanggaeto Plan 2.0* has detailed 1190MHz of spectrum between 700MHz and 6GHz which it wishes to release to mobile services by 2023. This includes 40MHz of 700MHz spectrum released as part of the digital dividend, which is considered already secured for mobile use (though no announcements have been made regarding when the released spectrum will be auctioned). Phase 2 of the Ministry's plan includes assigning at least 160MHz of spectrum in the 3.5GHz band by 2018. A further licence for use of 2.3GHz spectrum will also be assigned.

- **Thailand** – The lower C-band (3.4–3.6GHz) is currently used exclusively for fixed-satellite services, but the National Broadcasting and Telecommunications Commission has stated that alternative uses for the spectrum are 'under study', and has indicated that it would like to follow market trends regarding use of the band, in order to ensure benefits for telecoms communities. While the regulator itself has made no public comments on the L-band, in ACMA's 2012 discussion regarding mobile broadband in the 1.5GHz band, ACMA cites Thailand as one of the countries in the Asia–Pacific region that is interested in using the 1.5GHz band for mobile broadband services. Plans to award 1800MHz spectrum for 4G use have been suggested and it is also understood that further spectrum in the 2.3GHz band will be made available for commercial mobile and wireless broadband use

- **Vietnam** – Digital switchover was completed in May 2014, but there have been no announcements of plans to assign the released spectrum to mobile telecoms, and the release of the 700MHz band for the provision of LTE services. The Vietnam Telecommunications Authority has stated to the APT that it would support the 1452–1492MHz band as a potential candidate band; in particular it is interested in the development of sharing studies to identify a suitable band for IMT. Spectrum between 3.4–3.6GHz is currently used exclusively for fixed-

[25] http://www.gtigroup.org/news/ind/2014-12-25/5208.html

satellite services, and while the regulator has indicated that it does not plan to allow other applications in this band in the future, it has suggested it would be comfortable with the band being identified for future use by mobile, as long as such use takes into account that the C-band satellite networks play an important role in cases of disaster and so their continued operation needs to be protected.

Based on current spectrum assignments and how these compare to mobile connections, we have assessed the need for additional spectrum in our benchmark Asia–Pacific countries. As shown in Figure 5.5 below, our analysis indicates a need for additional mobile spectrum in all eight of the countries considered in this section. However we would expect the need to be most urgent in China, India and Indonesia, where 3G and 4G spectrum will be below 1Hz per connection in 2018 unless further spectrum is released.

Figure 5.5: Level of need for additional mobile spectrum in benchmark countries [Source: Analysys Mason, 2014]

	Shortfall from GSMA's spectrum target for 2020	3G & 4G spectrum per connection in 2018 (Hz per connection)	Additional mobile spectrum needs
Australia	942-1142MHz	14.38	✓
China	1123-1323MHz	0.33	✓✓✓
India	1220-1420MHz	0.33	✓✓✓
Indonesia	1254.25-1454.25MHz	0.69	✓✓✓
Japan	954-1154MHz	3.52	✓✓
South Korea	1240-1440MHz	7.79	✓✓
Thailand	1241-1441MHz	1.84	✓✓
Vietnam	1240-1440MHz	2.56	✓✓
KEY:	✓ Some need for additional mobile spectrum ✓✓ Significant need for additional mobile spectrum ✓✓✓ Urgent need for additional mobile spectrum		

5.3 Impact of further spectrum being available

While increases in spectrum availability will increase the capacity of mobile networks, enabling them to better meet mobile data demand, it will also bring about increases in both the quality and speed of mobile broadband services. As shown in Figure 5.6 below, there is a strong correlation between the carrier size used for the provision of LTE-A services and the peak throughput achieved; this highlights the fact that the spectrum needed for operators to offer the highest speeds to consumers is increasing as mobile technology evolves.

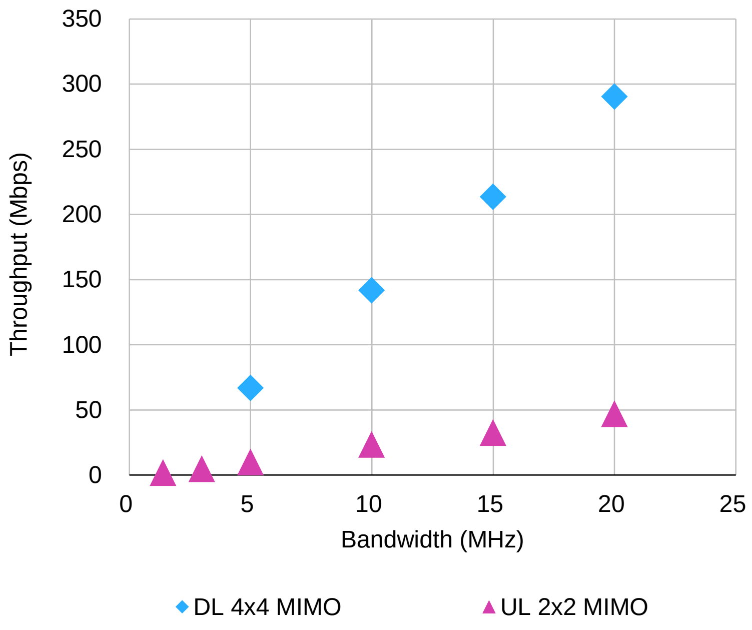


Figure 5.6: Peak throughput for different carrier sizes for LTE-A technologies [Source: Analysys Mason, Huawei, 2014]

The increase in mobile broadband quality and speed brought about by additional spectrum availability is likely to make mobile broadband services more attractive, increasing take-up in areas where the services are available, as well as encouraging more people to take the higher-end products (e.g. migrating away from 2G services or towards 4G services). Additionally, this higher demand for mobile broadband services may induce operators to extend their coverage.

For a number of the new mobile broadband subscribers who are attracted by the service's improved quality, this will be their first mobile or fixed broadband connection, and they will therefore pass on the full improvements to GDP and jobs calculated for an additional broadband connection in Section 4 above. The proportion of additional mobile broadband subscribers for whom this will be their first broadband connection is likely to be higher in emerging economies, such as India, where current penetration is low and the demographics and infrastructure are less amenable to fixed services than in countries like South Korea.

Beyond the economic benefits of increased broadband connections penetration discussed in Section 4, there are likely to be some benefits arising from the increase in *mobility*, such as the ability to use the service on the train, as well as the higher quality making it easier to use data-intensive mobile services. This will lead to an increase in traffic beyond that from the increase in subscriptions. The effect of mobility on economic value might be to some extent non-linear, as shown in Figure 5.7 below, with thresholds both where speeds start to be 'useful' and where most of the value has already been achieved.

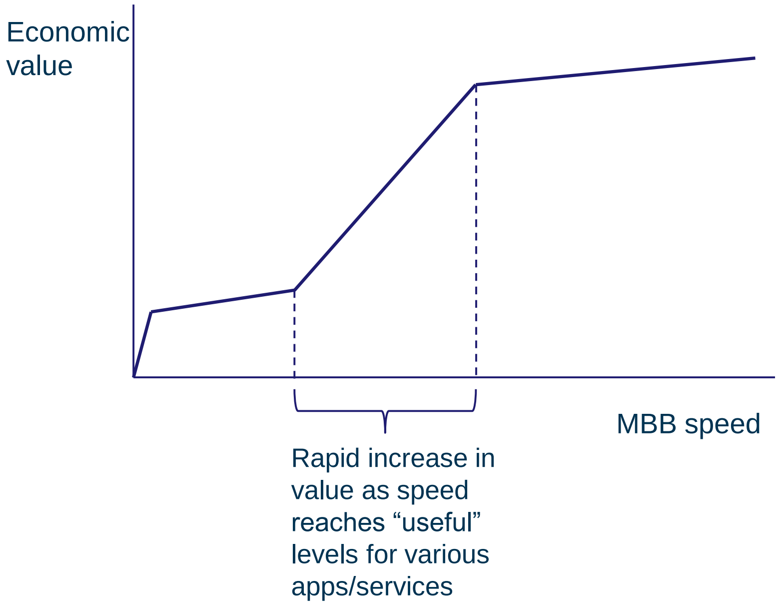


Figure 5.7: Illustrative relationship between mobile broadband speeds and additional economic value from mobility [Source: Analysys Mason, 2014]

5.4 Implications

In considering how to meet future mobile spectrum needs, national regulators and policy makers face difficult choices when trying to make spectrum available for mobile use whilst also protecting the needs of existing service. Various options are open to achieve a better use of spectrum, enabling re-allocation of portions of bands to occur – for example, by concentrating existing services into particular sub-bands, deploying new technologies that require less spectrum, or making use of alternative bands for existing services.

Ultimately these choices should be guided by the benefits from the use of different bands for new mobile use, relative to the costs of alternative options to meet existing users' needs.

A key requirement from the mobile industry's perspective is that, as with previous bands identified for IMT use, additional spectrum must be identified to support future IMT services as much as possible at a global level, to avoid fragmentation between regions. Once identified at a global level, further harmonisation also needs to take place at a regional level so that, for example, countries in the Asia–Pacific region implement new mobile spectrum bands in a coherent way across the different national markets. Since the current spectrum landscape for 2G,3G and 4G within the region is somewhat fragmented, it is important that policy makers and key industry stakeholders work together to achieve a more consistent framework in future in relation to the way that different mobile bands are deployed and used.

As a complement to identifying more spectrum globally for mobile use, we expect that more advanced approaches to spectrum sharing will be explored, including approaches such as licensed shared access (now being considered at a European level). The gradual take-up of small-cell layers, with their reduced output power and the exploitation of higher frequencies (offering higher radio frequency signal attenuation) will also facilitate future exploitation of sharing opportunities as well as improvement in overall spectrum utilisation.

Annex A Mobile broadband usage and trends – case studies

As set out in Section 3.2, mobile broadband subscriptions and traffic continue to grow rapidly across the Asia–Pacific region. However within the Asia–Pacific region there are significant differences in the demographic and economic status of countries, which, along with differences in the regulatory intervention, has resulted in differences in how mobile networks have developed. We have taken a closer look at mobile broadband usage and trends in a number of benchmark countries in Sections A.1 to A.6 below.

A.1 China

A.1.1 Introduction

Of our benchmark countries, China has the highest population and largest labour force; although with an area of 9.7 million km^2 it has a relatively low population density (as shown in Figure A.1). It is one of two countries within our benchmark with a GDP per capita below USD10 000 and is alone in having a relatively equal split of employment across sectors.

Demographics	
Area (km^2)	9.7 million
Population (million)	1360
Population density (people per km^2)	140
Economy	
GDP (USD billion)	9200
GDP/per capita (USD)	6800
Human Development Index	0.719 (91st out of 187)
Labour force (million)	800
Relative size of employment sectors (agriculture/industry/services)[26]	36.7/28.7/36.4
ICT Indicators	
ICT Development Index (2012)	4.18 (78th of 157)
Broadband connections penetration 2013	50%
Broadband connections penetration 2020	93%
Δ broadband connections penetration (2013– (percentage point)	43%

*Figure A.**1**: China 2013 country profile [Source: Analysys Mason, World Bank, EIU, ITU, 2014]*

[26] Data for 2010

The ITU's ICT Development Index in 2012 ranks China 78th out of the 157 countries reviewed, with a score of 4.18. Factors that have influenced this score are an international internet bandwidth of 4Mbit/s per internet user, with 42.3% of the population using the internet.

A.1.2 Mobile broadband developments

China is served by three wireless operators – China Mobile, China Unicom and China Telecom – and each operator provides 2G, 3G and 4G services to their customers using a range of technologies as shown in Figure A.2.

Figure A.2: Mobile operators and technologies [Source: Analysys Mason, 2014]

Operator	Technology	Launch date	Spectrum used
China Mobile	GSM→GPRS→ EDGE	1997	900/1800MHz
	TD-SCDMA	2009	2000MHz
	TD-LTE	2013	1900MHz 2300MHz 2600MHz
China Telecom	CDMA→ CDMA2000	2002	800MHz
	1xEV-DO Rev A	2009	1900MHz
	1xEV-DO Rev B	2009	850/2100MHz
	TD-LTE	2014	2600MHz
China Unicom	GSM→GPRS	1995	900MHz
	W-CDMA→ HSPA+→ DC-HSPA	2009	2100MHz
	TD-LTE	2014	2600MHz

3G spectrum concessions were allocated in January 2009, allowing the launch of mobile broadband services later that year. 4G services were launched in 2014 using TD-LTE technology – that is LTE using time-division duplex (TDD) in unpaired spectrum rather than frequency-division duplex (FDD) as predominantly used elsewhere. Both mobile broadband devices and smartphone connections are data-intensive, and therefore we consider them to collectively be mobile broadband connections. These have grown significantly from their 2009 level of 35.5 million to 483.1 million in 2013, and we expect them to continue to grow to 854.7 million in 2018, at which point there will be 3.5 times as many mobile broadband connections as fixed broadband connections.

The average volume of data traffic originating from each mobile connection is also increasing, with growth rates of between 21% and 32% CAGR forecast depending on the device type. This is partly a reflection of the move towards devices that are associated with higher data usage: the proportion of mobile handsets that are (more data-intensive) smartphones grew from 0% in 2008 to 44% in 2013 and they are expected to rise further to 61% in 2018.

The increase in the number of mobile data connections and the traffic per connection have a multiplicative effect on cellular data traffic[27] in China, which is expected to grow at a CAGR of 55% between 2014 and 2019 to reach almost 15 000PB by 2019.

It is noted that the estimates above do not capture the totality of data traffic that originates from mobile devices in China, since significant amounts of further traffic is currently carried by Wi-Fi.

A.1.3 Spectrum policy and predictions

Despite the significant amount of Wi-Fi use in China, it is generally recognised that additional spectrum for mobile networks will be required. China's statements to the ITU predict that a total of 570–690MHz will be required for IMT services by 2015 and 1490–1810MHz by 2020. This represents an increase of 93–213MHz and 1013–1333MHz from the 477MHz currently available in 2015 and 2020 respectively.

The MIIT has announced plans to allocate 30MHz of paired spectrum in the 1800MHz band to China Telecom, and 25MHz of paired spectrum in the 2.1GHz band to China Unicom for FDD deployments, providing an additional 110MHz of spectrum. The government is considering spectrum from within both the L-band and C-band for TD-LTE allocation to meet future demand for mobile broadband.

A.1.4 Conclusions

As of 2014, there are three mobile operators in China offering 2G, 3G and 4G services, accounting for 1.06 billion mobile connections. Of these, roughly 575 million are mobile broadband connections, while the others are for basic mobile handsets. These services have provided capacity for the 1618PB of cellular data traffic generated in the year.

However, with both connections and traffic per connection forecast to grow such that traffic will grow to 5945PB in 2019 (a CAGR of 55%), it is likely that the 477MHz of spectrum currently assigned to mobile services will not be sufficient to accommodate this traffic. An additional 110MHZ of spectrum in the 1800MHz and 2.1GHz bands is earmarked for mobile use and the government has expressed interest in using spectrum from within both the L-band and C-band for TD-LTE.

27 That is, data traffic carried over mobile networks and not offloaded to Wi-Fi

A.2 Australia

A.2.1 Introduction

Australia's size and relatively low population, of 24 million, give it the lowest population density of the countries in our benchmark set at 3.0 inhabitants per km^2. As shown in Figure A.3 below, Australia has a GDP per capita of USD67 500, the highest in our benchmark set, with over 75% of jobs in the tertiary (services) sector.

Demographics	
Area (km^2)	7 692 024
Population (million)	24
Population density (people per km^2)	3.0
Economy	
GDP (USD billion)	1561
GDP/per capita (USD)	67 468
Human Development Index	0.933 (2nd out of 187)
Labour force (million)	12
Relative size of employment sectors (agriculture/industry/services)[28]	3.3/21.1/75.5
ICT Indicators	
ICT Development Index (2012)	7.90 (11th of 157)
Broadband connections penetration 2013	126%
Broadband connections penetration 2020	162%
Δ broadband connections penetration (2013–2020) (percentage point)	37%

Figure A.3: Australia 2013 country profile [Source: Analysys Mason, World Bank, EIU, 2014]

The ITU's ICT Development Index in 2012 ranks Australia 11th out of the 157 countries reviewed with a score of 7.90. Factors that have influenced this score are an international internet bandwidth of 69Mbit/s per internet user, with 82.3% of the population using the internet.

A.2.2 Mobile broadband developments

Australia's mobile market is served by three network operators with all three having deployed LTE services by 2013 as shown in Figure A.4.

[28] Data for 2009

Figure A.4: Mobile operators and technologies [Source: Analysys Mason, 2014]

Operator	Technology	Launch date	Spectrum used
Optus	GSM→GPRS	1993	900/1800MHz
	W-CDMA→ HSPDA→ HSPA+	2005	2100MHz
	W-CDMA→ HSPDA→ HSPA+	2008	900MHz
	LTE	2012	2100MHz
	TD-LTE	2012	2.3GHz
	LTE	2014	2.6GHz
	LTE	2015 (planned)	700MHz
Telstra	GSM→GPRS→ EDGE	1993	900/1800MHz
	W-CDMA→ HSPA+→ HSUPA→ DC-HSPA	2006	850MHz
	LTE	2011	1800MHz
	LTE	2014	700/1800MHz
Vodafone	GSM→GPRS→ EDGE	1993	900/1800MHz
	W-CDMA→ HSPDA→ HSPA+	2003	2100MHz
	HSPA+→ DC-HSPA+	2011	850MHz
	LTE	2013	1800MHz

While fixed broadband penetration is high, boosted by the availability of fibre due to government fibre-optic network initiatives, mobile broadband device connections overtook the number of fixed broadband connections in 2013. Mobile and wireless communications play an important role, particularly due to the country's geography and population dispersal, and it is widely used as an alternative to fixed broadband connectivity.

While mobile connections are forecast to grow at a CAGR of 4% in the period to 2018, the volume of traffic originating from each connection is expected to grow at a CAGR of between 19% and 58% depending on device type. This is a reflection of the high levels of smartphone adoption in Australia (growing from 76% of handsets in 2013 to 92% in 2018) and the accelerated LTE network roll-outs that are together driving LTE take-up across the country. Of particular note is the 11-fold growth in traffic per dongle/router expected to arise between 2014 and 2019, while over the same period, there will be a tripling of growth in traffic per 3G/4G handset, and a doubling of growth in traffic per mid-screen device.

As a result of both the growth in devices and the amount of data generated per device, Australia's mobile data traffic is forecast to grow at a CAGR of 37% between 2014 and 2019. This will result in annual traffic increasing by a factor of seven to reach 1487PB per year in 2019. Further wireless data traffic will be carried via Wi-Fi

A.2.3 Spectrum policy and predictions

The ACMA is not of the opinion that the available spectrum will be sufficient to satisfy long-term demand and has proposed to prioritise more spectrum for mobile broadband usage in both its 2011 *Towards 2020 – Future Spectrum Requirements for Mobile Broadband* document and its 2014 *Five year Spectrum Outlook*. In total, the ACMA is looking to make 1100MHz of spectrum available to mobile services by 2020.

There has been particular focus on parts of the C-band, L-band and the 2.7–2.9GHz spectrum. The 3.4GHz band (3425–3575MHz) was auctioned for fixed wireless access in 2000, with licences due to expire on 13 December 2015. On 18 June 2014, ACMA released a consultation paper on changing the status of the 3.4–3.6GHz band, moving towards use of this band for fixed and mobile broadband services. In May 2011, ACMA identified spectrum including 1427.9–1462.9MHz, 1475.9–1510.9MHz and 2.7–2.9GHz as candidate bands for mobile broadband usage in its *Towards 2020* strategy, and ACMA is likely to consider these bands for future mobile broadband services. It has announced plans to conduct a review of the L-band spectrum in 2015/2016 to consider potential future use of this band by mobile services including consideration of the outcomes of the WRC-15 before progressing work domestically; it is possible that this will result in a move towards using the 1452–1492MHz band plan.

A.2.4 Conclusions

Australia's three mobile network operators provided network services to 28 million mobile connections in 2013, using 2G, 3G and 4G technologies. Due in part to Australia's geography and demographics, mobile broadband connectivity is of particular importance and is often seen as an alternative to fixed broadband infrastructure. Connections are forecast to reach 34 million in 2018, with 4G accounting for a growing share (rising from 20% to 50% between 2013 and 2018). The volume of data traffic originating from each cellular connection is also rising; the expected seven-fold increase in cellular data traffic equates to 1487PB of traffic per mobile broadband connection by 2019.

While Australia has the highest amount of spectrum assigned to mobile usage of all the countries profiled in this report (with a total of 658MHz currently assigned to mobile technologies), operators have yet to commercially launch services over the spectrum that was awarded in 2013 (i.e. 60MHz of spectrum in the 700MHz band and 140MHz of spectrum in the 2.6GHz band) as it is not yet considered 'available'. A substantial amount of spectrum, including that in the C-band, L-band and between 2.7–2.9GHz, has been discussed as holding potential for future release.

A.3 Hong Kong

A.3.1 Introduction

Hong Kong has a highly dense population of 6845.2 people per km^2, as shown in Figure A.5 below. Its population of 7 million has a GDP per capita of USD38 000 generated by a labour force of 4 million, the vast majority of whom (over 87%) work in the tertiary sector.

Demographics	
Area (km^2)	1104
Population (million)	7
Population density (people per km^2)	6845.2
Economy	
GDP (USD billion)	274
GDP/per capita (USD)	28 124
Human Development Index	0.891 (15th out of 187)
Labour force (million)	4
Relative size of employment sectors (agriculture/industry/services)[29]	0.2/12.4/87.4
ICT Indicators	
ICT Development Index (2012)	7.92 (10th of 157)
Broadband connections penetration 2013	157%
Broadband connections penetration 2020	218%
Δ broadband connections penetration (2013–2020) (percentage point)	61%

*Figure A.**5**: Hong Kong 2013 country profile [Source: Analysys Mason, World Bank, EIU, 2014]*

The ITU's ICT Development Index in 2012 ranks Hong Kong tenth out of the 157 countries reviewed with a score of 7.92. Factors that have influenced this score are an international internet bandwidth of 1240Mbit/s per internet user, with 72.8% of the population using the internet.

A.3.2 Mobile broadband developments

Hong Kong has the highest mobile SIM penetration in the Asia–Pacific region at 208%; this is a reflection of the high level of competition between the five mobile operators present in the market, as shown in Figure A.6 below. Prior to 2005, when CSL and New World Mobility merged to form CSL Limited, the market was even more competitive with six mobile operators.

29 Data for 2009

Figure A.6: Mobile operators and technologies [Source: Analysys Mason, 2014]

Operator	Technology	Launch date	Spectrum used
China Mobile	GSM→GPRS→ EDGE→ LTE	1997	1800MHz
	LTE	2012	2.6GHz
	TD-LTE	2012	2.3GHz
CSL Limited	GSM→GPRS→ EDGE→ LTE	1993	900/1800MHz
	W-CDMA→DC-HSPA+	2004	900/2100MHz
	LTE	2010	2.6GHz
H3G	GSM→GPRS	1998	900/1800MHz
	W-CDMA→DC-HSPA+	2004	900/2100MHz
	LTE	2012	2.6GHz
	LTE	2012	1800MHz
	TD-LTE	2014	2.3GHz
PCCW	GSM→GPRS→ EDGE	1997	1800MHz
	CDMA2000→1xEV-DO Rev	2008	850MHz
	W-CDMA→DC-HSPA+	2008	2100MHz
	LTE	2012	2.6GHz
	LTE	2012	1800MHz
SmarTone	GSM→GPRS→	1993	900/1800MHz
	W-CDMA→DC-HSPA+	2004	850/2100MHz
	LTE	2012	1800MHz
	LTE	2014	2.6GHz

2100MHz licences were re-auctioned on 8 December 2014, with spectrum awarded to China Mobile, H3G and SmarTone. The license period is due to commence on 22 October 2016 at which point it is likely the operators will launch LTE networks using this spectrum.

The operators in Hong Kong have historically been early adopters of new network technologies, with the first 3G services launched by H3G in 2004. Additionally all five operators launched commercial LTE networks between 2010 and 2012 and are continuing to try to differentiate themselves by offering better services, for example in February 2014 CSL started deploying 300Mbit/s LTE-CA.

While the existing high mobile penetration in Hong Kong means that there is little scope for further growth in terms of multiple-SIM ownership, mobile broadband device connections are growing rapidly, from 0.7 million in 2008 to 2.4 million in 2013, or a 33% population penetration of such devices, with more data intensive 4G handset connections also growing as subscribers move away from 2G services. Mobile broadband device connections are expected to overtake fixed broadband in 2015, growing to 2.8 million in 2018.

The traffic originating from each connection is also growing. In particular, data traffic from handsets and mid-screen devices are expected to grow at CAGR of 31% and 32%, respectively, over the 2014–19 period. This reflects the move to more data-intensive devices such as smartphones; the penetration of these handsets rose from 16% in 2009 to 53% in 2013, and is expected to increase even further to 86% by 2018.

As a result of this growth in data-intensive devices and data generated per device, mobile data traffic in Hong Kong is forecast to grow at a CAGR of 38% in the period to 2019. Traffic will therefore increase by a factor of five – from 175PB per year in 2014 to 858PB per year in 2019. Further traffic will be carried via Wi-Fi.

A.3.3 Spectrum policy and predictions

As part of the implementation of the Radio Spectrum Policy Framework announced by the government in April 2007, the Communications Authority in Hong Kong regularly publishes a spectrum release plan to inform the industry of the potential supply of radio spectrum for the following three years. The Spectrum Release Plan for 2014–16 sets out that 39.2MHz of spectrum in the 1930–2160MHz band is planned for release to mobile services. However this spectrum is already in use by mobile network operators for the provision of 3G mobile services, with the assignments due to expire on 21 October 2016. Therefore, this release does not represent new bandwidth being made available for mobile service provision, simply a re-assignment of the spectrum with more flexible licensing conditions regarding technology.

A.3.4 Conclusions

The mobile market in Hong Kong is highly competitive, with five operators, resulting in multiple-SIM ownership and early deployments of new technologies. These operators support 15 million mobile connections; while the volume of connections is expected to remain steady over the 2013–18 period, the share of 4G connections is forecast to rise from 15% to 59% over the same period.

These services provide capacity for the 175PB of cellular data traffic generated in each year, with both connections and traffic per connection forecast to grow such that traffic will grow at a CAGR of 38% to 858PB in 2019. There is currently no additional spectrum expected to be released to serve the forecast increase in mobile data traffic in Hong Kong and it is likely that the existing network capacity will not be sufficient to serve this increased demand, particularly given the high population density in Hong Kong, and more spectrum will be required.

A.4 India

A.4.1 Introduction

India, with its large population of over 1.2 billion, has the lowest GDP per capita of the countries studied, at USD1500. As shown in Figure A.7, the country has a labour force of 493 million, less than 40% of the population; over 50% of this labour force works in agriculture.

Demographics	
Area (km^2)	3 287 590
Population (million)	1256
Population density (people per km^2)	421.1
Economy	
GDP (USD billion)	1877
GDP/per capita (USD)	1499
Human Development Index	0.596 (135th out of 187)
Labour force (million)	493
Relative size of employment sectors (agriculture/industry/services)[30]	51.1/22.4/26.6
ICT Indicators	
ICT Development Index (2012)	2.12 (121st of 157)
Broadband connections penetration 2013	9%
Broadband connections penetration 2020	44%
Δ broadband connections penetration (2013–2020) (percentage point)	35%

*Figure A.**7**: India 2013 country profile [Source: Analysys Mason, World Bank, EIU, 2014]*

The ITU's ICT Development Index in 2012 ranks India 121st out of the 157 countries reviewed with a score of 2.12. Factors that have influenced this score are an international internet bandwidth of 5Mbit/s per internet user, with 12.6% of the population using the internet.

30 Data for 2010

A.4.2 Mobile broadband developments

The Indian mobile market is overcrowded, containing 13 network operators competing for market share, many of whom only hold spectrum in one frequency band as shown in Figure A.8. Current LTE roll-outs are limited to those of Aircel and Bharti Airtel in the 2.3GHz band due to a lack of suitable spectrum availability.

Figure A.8: Mobile operators and technologies [Source: Analysys Mason, 2014]

Operator	Technologies	Spectrum holdings
Aircel	2G, 3G, 4G	900MHz, 1800MHz, 2100MHz, 2.3GHz
BSNL	2G, 3G	800MHz, 900MHz, 2100MHz
Bharti Airtel	2G, 3G, 4G	900MHz, 1800MHz, 2100MHz, 2.3GHz
Idea	2G, 3G	900MHz, 1800MHz, 2100MHz
Loop	2G	900MHz
MTNL	2G, 3G	900MHz, 1800MHz, 2100MHz
Quadrant	2G	800MHz, 1800MHz
RCOM	2G, 3G	900MHz, 1800MHz, 2100MHz
RJIL	4G	1800MHz, 2.3GHz
SSTL	2G, 3G	800MHz
Tata	2G, 3G	800MHz, 1800MHz, 2100MHz
Uninor	2G	1800MHz
Videocon	2G	1800MHz
Vodafone	2G, 3G	900MHz, 1800MHz, 2100MHz

Although mobile broadband take-up is growing rapidly (at a CAGR of 23%), penetration remains low at 2%, expected to rise to 5% in 2018. However mobile broadband device connections overtook fixed broadband in 2012 and the slower growth rate of fixed connections (CAGR of 11%) means the difference is growing.

While mobile connections in India remain relatively few in number, the traffic generated by each is growing, with growth rates of 28% and 22% CAGR forecast for mid-screen devices and dongle/routers respectively between 2014 and 2019. Data traffic generated on 3G and 4G handsets is also expected to experience significant growth, at a CAGR of 32%.

As a result of both the growth in the number of devices in the market and data generated per device, India’s mobile data traffic is forecast to grow rapidly at a CAGR of 62%. This will result in cellular data traffic increasing to 11 605PB per year in 2019, an 11-fold increase.

A.4.3 Spectrum policy and predictions

The National Telecom Policy published by DoT in 2012 proposed a number of actions regarding further spectrum release to mobile in order to support backhaul in rural areas. The policy stated the need to make a total of 300MHz of additional spectrum available for IMT services by 2017 and a further 200MHz by 2020. In particular, it contains proposals to make available adequate globally harmonised IMT spectrum in the 450MHz, 700MHz, 1800MHz, 1910MHz, 2.1GHz, 2.3GHz, 2.5GHz and 3.5GHz bands, as well as other bands to be identified by ITU for commercial mobile services.

Since publication of the National Telecom Plan, a consultation has been released discussing further spectrum assignment to mobile usage in the 700MHz, 1800MHz, 1910MHz and 2.1GHz bands, to coincide with the expiration of a number of 900MHz and 1800MHz licences in 2015/16.

A.4.4 Conclusions

Of the Indian mobile market's 13 operators, only two have launched LTE services due to the limited availability of suitable spectrum. These operators support 779 million mobile connections, mostly for 2G services. While 2G will remain dominant for the medium term, 3G and 4G connections are, combined, expected to make up 35% of connections by 2018.

These services provide capacity for the 1028PB of cellular data traffic generated in 2014, with both the number of connections and the traffic per connection forecast to grow such that traffic will rise at a CAGR of 62% to 11 605PB in 2019. This significant increase in traffic means it is unlikely that the 360MHz of spectrum currently in use for mobile service provision will be sufficient. The national regulator, DoT, appears aware of this forthcoming spectrum shortage as it is looking to identify an additional 300MHz of spectrum to award to mobile by 2017 and a further 200MHz by 2020.

A.5 South Korea

A.5.1 Introduction

As shown in Figure A.9 below, South Korea has a relatively high GDP per capita at roughly USD26 000. Of its population of 51 million, 26 million are members of the labour force; this labour force experiences an unemployment rate of only 3% and is focused in the tertiary sector.

Demographics	
Area (km^2)	100 210
Population (million)	51
Population density (people per km^2)	515.9
Economy	
GDP (USD billion)	1305
GDP/per capita (USD)	25 977
Human Development Index	0.891 (15th out of 187)
Labour force (million)	26
Relative size of employment sectors (agriculture/industry/services)[31]	6.6/17.0/76.4
ICT Indicators	
ICT Development Index (2012)	8.57 (1st of 157)
Broadband connections penetration 2013	118%
Broadband connections penetration 2020	154%
Δ broadband connections penetration (2013–2020) (percentage point)	36%

*Figure A.**9**: South Korea 2013 country profile [Source: Analysys Mason, World Bank, EIU, 2014]*

The ITU's ICT Development Index in 2012 ranks South Korea first out of the 157 countries reviewed with a score of 8.57. Factors that have influenced this score are an international internet bandwidth of 26Mbit/s per internet user, with 84.1% of the population using the internet.

A.5.2 Mobile broadband developments

The South Korean mobile market is served by three operators who compete with rapid adoption of new technologies. 3G services were launched in 2005 and 4G in 2011 and, as shown in Figure A.10, all operators offer LTE-A services. This upgrade to LTE-A is in part to cope with the significant growth in the 4G subscriber base.

[31] Data for 2010

Figure A.10: Mobile operators and technologies [Source: Analysys Mason, 2014]

Operator	Technology	Launch date	Spectrum used
KT Corp	CDMA2000	2002	1700MHz
	W-CDMA→HSUPA	2003	2100MHz
	LTE	2012	1800MHz
	LTE→LTE-	2013	800/1800MHz
LG Uplus	CDMA→CDMA2000→1xEV-DO Rev	1997	1700MHz
	LTE→LTE-	2011	850MHz
	LTE→LTE-	2012	2100MHz
SK Telecom	CDMA→1xEV-DO Rev LTE→LTE-	1996	800MHz
	W-CDMA→HSPA+	2003	2100MHz
	LTE→LTE-	2012	1800MHz

While there are over 28 million 4G connections in South Korea in 2013, mobile broadband device connections remain low at 1.6 million, while fixed broadband connections are close to 20 million. While mobile broadband connections are expected to grow more rapidly, at a CAGR of 6% rather than the 1% for fixed broadband, they will not exceed 10% of the number of fixed broadband subscriptions in 2018.

The traffic originating from each of these connections, both handsets and other mobile broadband devices, is also growing, and data usage has significantly increased since the 2011 launch of 4G services, both on 3G and 4G networks as 3G networks become less congested and perform better. Average traffic for handsets and mid-screen devices is expected to grow at CAGRs of 29% and 22% respectively from 2014 to 2019.

As a result of both the growth in the number of devices in the market and data generated per device, mobile data traffic in South Korea is forecast to grow at a CAGR of 31%. This will result in cellular data traffic increasing by a factor of four between 2014 and 21019 – from 1137PB to 4333PB per year. Further traffic will be carried via Wi-Fi.

A.5.3 Spectrum policy and predictions

The South Korean Ministry of Science, ICT & Future Planning has published its Mobile Gwanggaeto Plan 2.0 detailing the additional 1190MHz of spectrum, between 700MHz and 6GHz, which it wishes to release to mobile services by 2023. This includes 40MHz of 700MHz spectrum released by the digital dividend, which is considered already secured for mobile use. Phase 2 of the Ministry's plan includes assigning at least 160MHz of spectrum in the 3.5GHz band by 2018.

The Ministry has additionally stated to the APT that it would support the 1452–1492MHz band as a potential candidate band to be globally allocated to mobile services on a primary basis.

A.5.4 Conclusions

The South Korean mobile market is served by three very competitive operators who compete with rapid adoption of new technologies, with all operators offering LTE-A services. These operators support 55 million mobile connections. The total number of connections is not expected to rise significantly, but these will shift towards 4G technology: which will account for 93% of connections by the end of 2018, with 2G connections being negligible. These services provide capacity for the 1137PB of cellular data traffic generated in 2014, with both connections and traffic per connection forecast to grow such that traffic will grow at a CAGR of 31% to 4333PB in 2019. This growth in traffic generated per connection means it is likely further spectrum capacity will be required, in line with regulatory goals set out by the Ministry of Science, ICT & Future Planning.

A.6 Singapore

A.6.1 Introduction

Singapore has the densest population of any of our benchmark countries at 7713 people per km^2 and a high GDP per capita of USD55 000, as shown in Figure A.11. The economy is predominantly focussed on the tertiary sector, with agriculture making up less than 2%.

Demographics	
Area (km^2)	716
Population (million)	6
Population density (people per km^2)	7713.1
Economy	
GDP (USD billion)	298
GDP/per capita (USD)	55 182
Human Development Index	0.901 (9th out of 187)
Labour force (million)	3
Relative size of employment sectors (agriculture/industry/services)[32]	1.1/21.8/77.1
ICT Indicators	
ICT Development Index (2012)	7.65 (15th of 157)
Broadband connections penetration 2013	123%
Broadband connections penetration 2020	167%
Δ broadband connections penetration (2013–2020) (percentage point)	43%

*Figure A.**11**: Singapore 2013 country profile [Source: Analysys Mason, World Bank, EIU, 2014]*

The ITU's ICT Development Index in 2012 ranks Singapore 15th out of the 157 countries reviewed with a score of 7.65. Factors that have influenced this score are an international internet bandwidth of 391Mbit/s per internet user, with 74.2% of the population using the internet.

A.6.2 Mobile broadband developments

Singapore's population is served by three mobile network operators, all of whom have had LTE services since 2012, as shown in Figure A.12.

[32] Data for 2009

Figure A.12: Mobile operators and technologies [Source: Analysys Mason, 2014]

Operator	Technology	Launch date	Spectrum used
M1	GSM→GPRS	1997	900MHz
	W-CDMA→HSUPA	2005	2100MHz
	LTE→LTE-	2012	1800/2600MHz
SingTel	GSM→GPRS	1994	900/1800MHz
	W-CDMA→HSPA+	2005	2100MHz
	LTE→LTE-	2011	1800/2100MHz
StarHub	GSM→GPRS	2000	1800MHz
	W-CDMA	2005	900/2100MHz
	W-CDMA→DC-HSPA+	2007	2100MHz
	LTE→LTE+	2012	1800/2600MHz

Fixed broadband penetration in Singapore is amongst the highest in the world, but mobile broadband device take-up is also high, in part a result of nationwide deployments of LTE. Population is expected to grow in Singapore at a considerably higher rate than its regional neighbours, allowing connections to rise despite the high mobile penetration level (145%). 25% of mobile subscriptions were 4G connections at the end of 2013, and this number is expected to account for 77% by 2018; mobile broadband connections are expected to exceed fixed connections in 2016.

The average volume of data traffic originating from these various mobile connections is also increasing, with growth rates of 28% and 31% CAGR forecast for handsets and mid-screen devices respectively. This in part reflects the move to more data-intensive devices: the proportion of mobile handsets that are smartphones is expected to grow from 60% in 2013 to 90% in 2018.

The increase in the number of mobile data connections and traffic per connection has a multiplicative effect on cellular data traffic which is expected to grow at a CAGR of 35% from 97PB in 2014 to 435PB in 2019.

This does not fully capture the growth in data traffic originating from handheld devices as there is additional traffic that is offloaded to Wi-Fi.

A.6.3 Spectrum policy and predictions

The IDA's 2014 Radio Spectrum Master Plan discusses the need for future IMT spectrum bands to provide 4G services. The IDA states that its primary interest is to give flexibility for 4G services to operate within the 450–470MHz, 698–960MHz, 2110–2200MHz, 2300–2400MHz, 2570-2620MHz and 3400-3600MHz bands while ensuring such services will not interfere with other services, such as, satellite or radar in the adjacent bands. Were the full spectrum in the relevant bands to be released to mobile use, a further 722MHz of spectrum would be available.

A.6.4 Conclusions

The mobile market in Singapore is served by three mobile network operators; all three have been offering LTE services since 2012. These operators support 8 million mobile connections, which are expected to rise to 9 million in 2018, while the share of these connections from 4G is set to rise from 25% in 2013 to 77% in 2018.

These services provide capacity for the 97PB of cellular data traffic generated in 2014, with both connections and traffic per connection forecast to grow such that traffic will rise to 435PB in 2019 (CAGR of 35%). It is likely that the existing network capacity will not be sufficient to serve this increased traffic, particularly given the high population density in Singapore. With traffic expected to more than quadruple by 2019, it is possible that even the additional 722MHz of spectrum proposed for assignment by the IDA will be insufficient.

Annex B Methodology for benefits estimation

B.1 Definition

We define ‘broadband’ to include both fixed and mobile network connections, including use of smartphones for data, but excluding basic mobile handsets.

B.2 Methodology

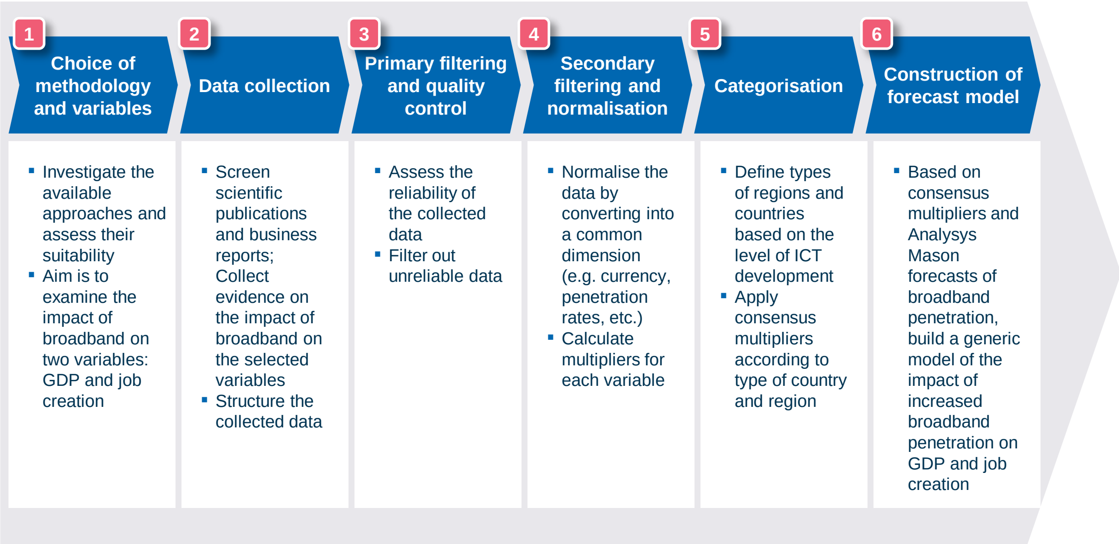
In order to arrive at the estimated impact of broadband connectivity on the economy, we have followed a robust six-step procedure. Screening over 130 reports, a number of factors have been taken into account in choosing an appropriate methodology, variables of interest and in performing filtering, normalisation and grouping of the collected data.

Three main methods are used when estimating the impact of broadband infrastructure investments on economic prosperity:

- Multivariate regression modelling – allows for analysing the relationship between a dependent variable and one or several independent variables; it is commonly used by researchers and higher educational institutions
- Input/output analysis – allows to analyse the effects that different sectors have on the economy as a whole
- Cost–benefit analysis –allows for a bottom-up assessment of the costs and benefits related to particular investment decisions.

A fourth method – the ‘multiplier approach’ – uses results from other studies and methods to arrive at consensus estimates. Due to the wide perspective and ease of understanding that the multiplier method offers, we utilised this approach in order to assess the impact of broadband connectivity on the economy. Since the multiplier method depends on the availability of studies already conducted on the subject and the soundness of their results we have gone through a robust procedure in filtering and normalisation of the selected studies and data points. A detailed overview of the methodology is presented in Figure B.1.

Figure B.1: Methodology used in assessing the economic benefits of broadband [Source: Analysys Mason, 2014]

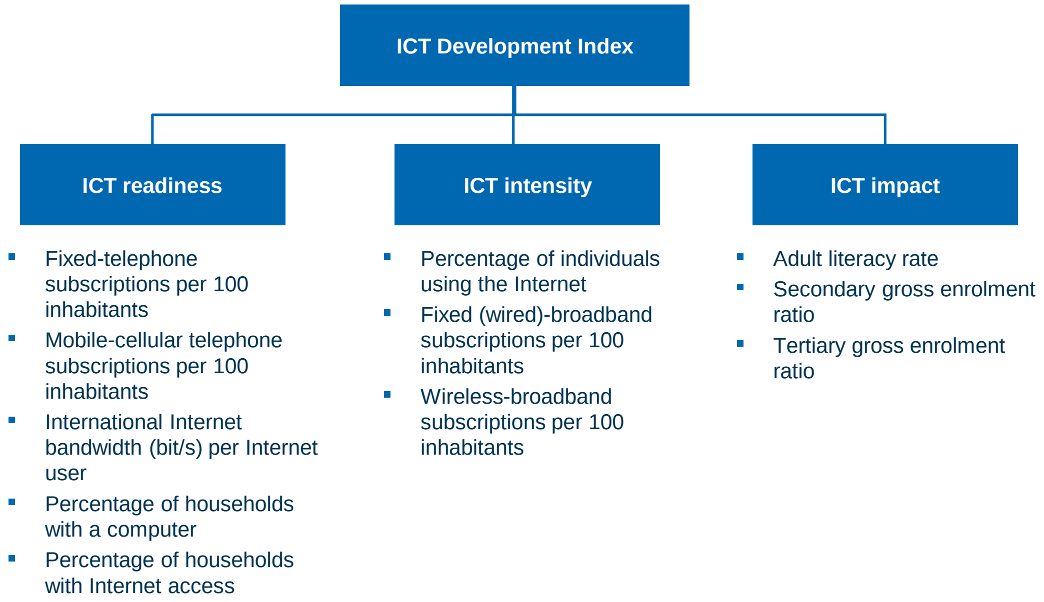


Surveying the available literature we found that GDP and employment are the most common measures of the impact of broadband connectivity. Other measures used include productivity improvements, new business creation, consumer surplus, etc. However, the available evidence on the impact of broadband connectivity on the latter variables was found to be insufficient for the development of a quantitative model. That is why we focused on investigating the impact on output and job creation, where the availability of proof points coming from previous studies was sufficient to quantify the impact.

We assessed the reliability of the collected studies and proof points and filtered out the unreliable data. We then normalised the remaining data set by performing conversion into common units.

Taking into account the network theory and the differentiated impact of broadband penetration on GDP and job creation, we have used the ICT Development Index as a proxy for ICT advancement. The ICT Development Index published by the ITU measures the level of advancement of ICT in more than 150 countries around the world, allowing comparison between countries. There are three main dimensions through which ICT maturity is assessed: ICT readiness, ICT intensity and ICT impact.

Figure B.2: Composition of the ICT Development Index [Source: International Telecommunication Unit (ITU), 2013]



Using the data from the filtered studies and the ICT development index, two groups of countries were formed: developed and emerging nations. The latter group of countries score between 2.2 and 5.2, whereas the former score above 5.2[33]. The countries of interest in the Asia–Pacific region were also classified according to these assumptions. In particular, Australia, Hong Kong, Singapore and South Korea fall in the ‘developed nations’ category, whereas India and China were classified as ‘emerging nations’.

Based on the filtered and categorised data points we estimated the multipliers for each of the variables of interest[34]. In order to account for the data spread caused by varying methodologies and differences of the countries studied in the filtered papers we took the median of the observed data set for each of the two groups of countries.

Drawing on forecasts by Analysys Mason Research of broadband connections penetration, as well as economic and demographic indicators, we built a generic model for each of the countries of interest in the Asia–Pacific region. The model allows for estimating the impact of increased broadband connections penetration on output and jobs.

33 Countries scoring below 2.2 were classified as less developed; however, since none of the countries of interest in the Asia–Pacific region is classified in this group, papers and data investigating the impact of broadband in less developed countries have been left out of the analysis.

34 Since few studies investigating the impact of broadband on job creation in developed nations, passed out the rigorous process of filtering and normalisation of variables, we used the multiplier estimates for emerging nations for this group as well.

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